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The Journal of
THE ROYAL AERONAUTICAL SOCIETY

JUNE 1946
NO. 426 VOL. 50

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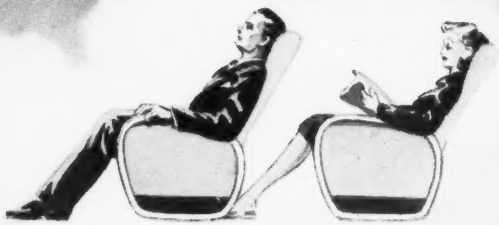

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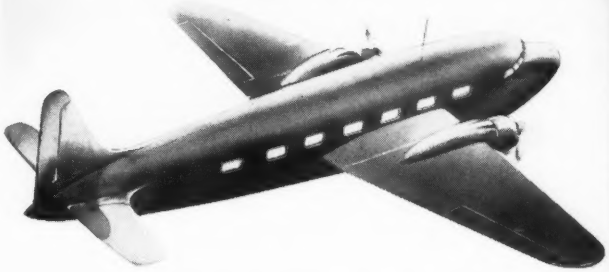

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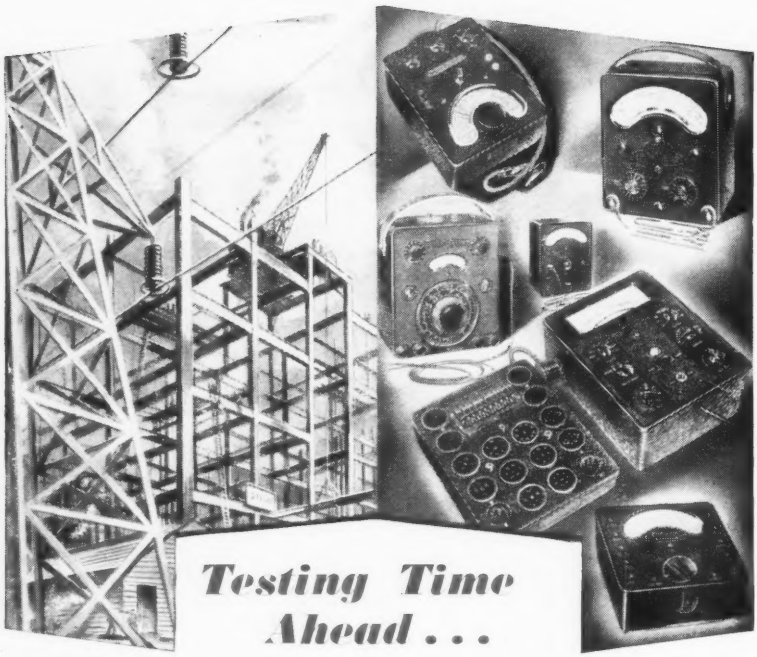

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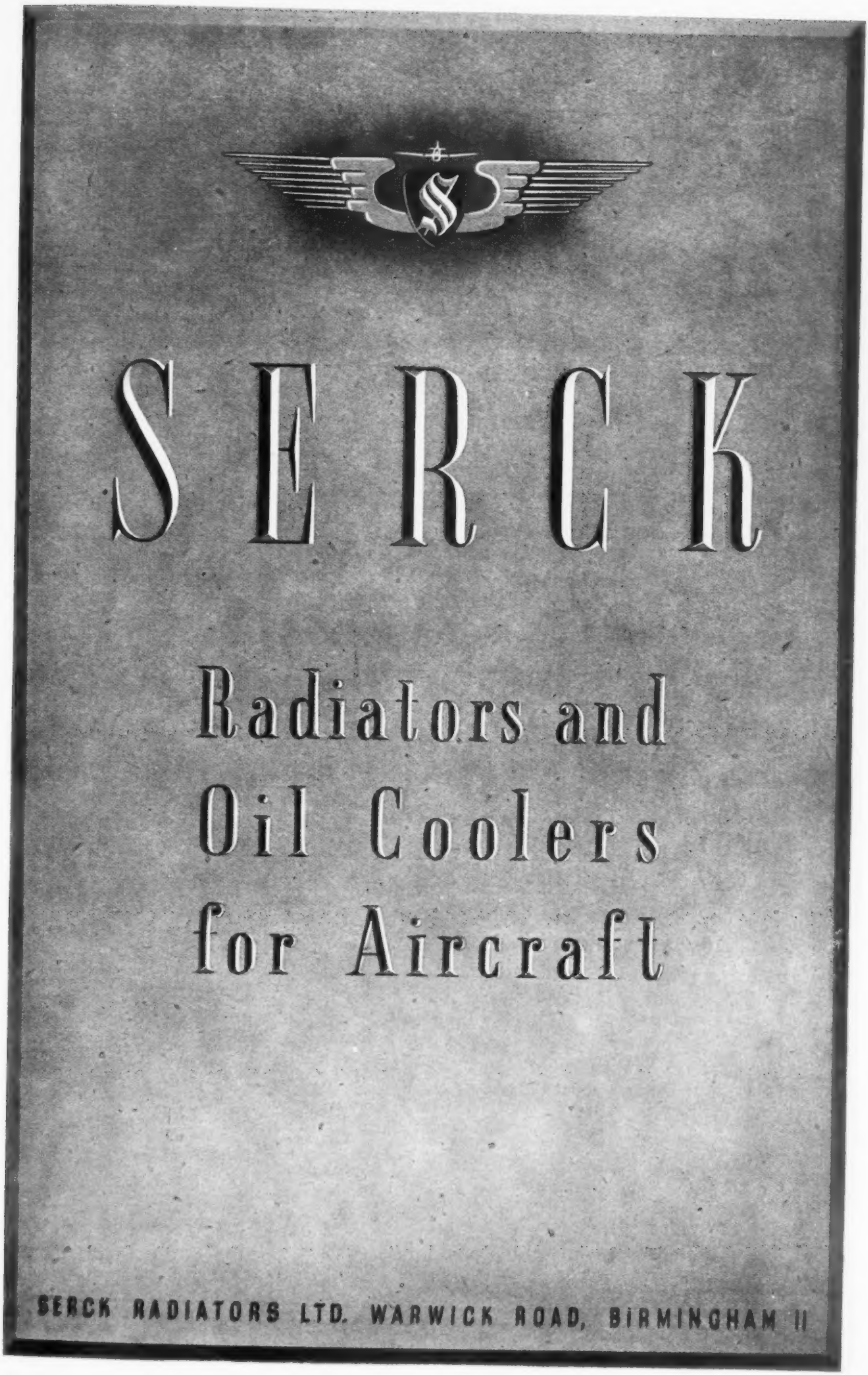
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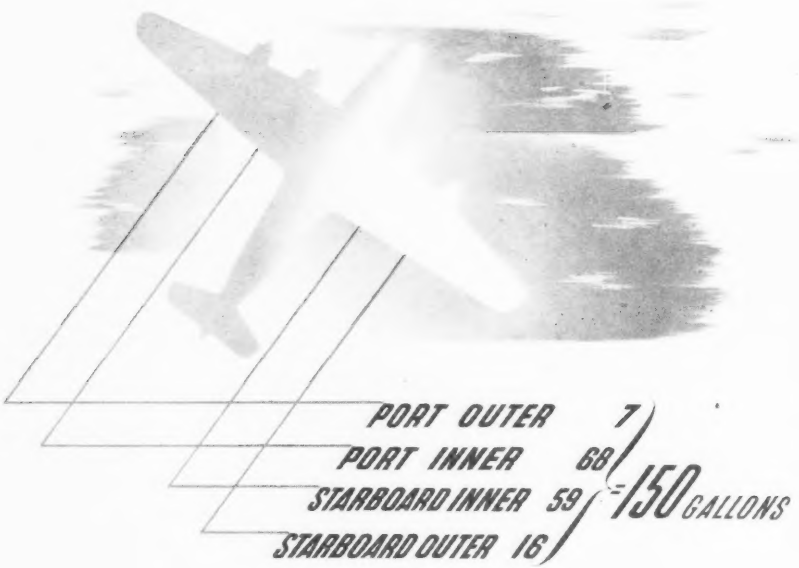

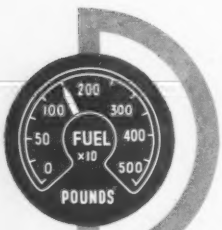

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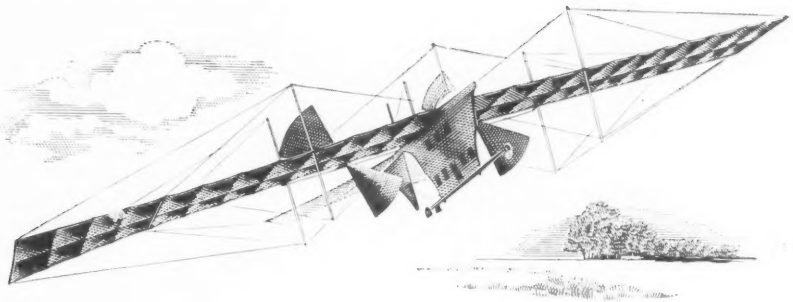

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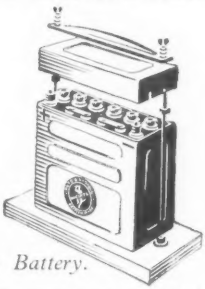

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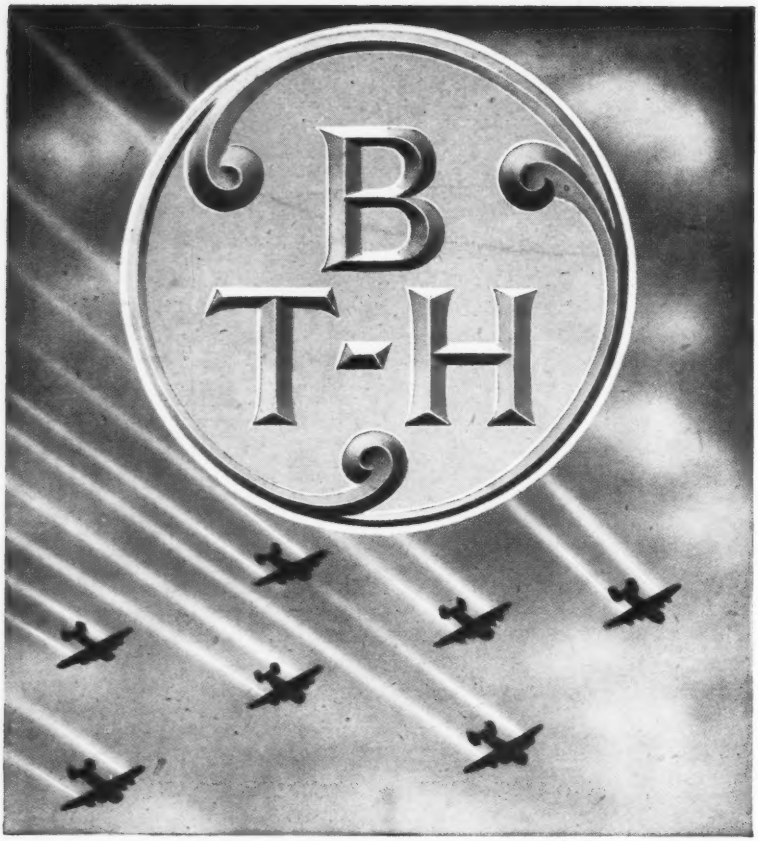

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The Journal of The Royal Aeronautical Society was founded in 1897 in succession to the Annual Reports. For the opinions expressed in Papers that are signed or initialled the authors alone are responsible. None of the papers or paragraphs must be taken as expressing the opinion of the Council of The Royal Aeronautical Society unless such is definitely stated to be the case. **The Journal is published monthly at the Offices of the Society, 4, Hamilton Place, Piccadilly, London, W.1.** Subscriptions per annum, £4 13 0 including postage; Single Numbers 7 6 or 7 9 post free. All communications for publication in the Journal, or on general matters affecting the Society should be addressed to — The Secretary, J. Laurence Pritchard, 4, Hamilton Place, W.1. The Society's Bankers are Messrs. Coutts and Co. All communications respecting Advertisement matters should be addressed to—The Advertisement Manager, Journal of The Royal Aeronautical Society, 4, Hamilton Place, W.1.

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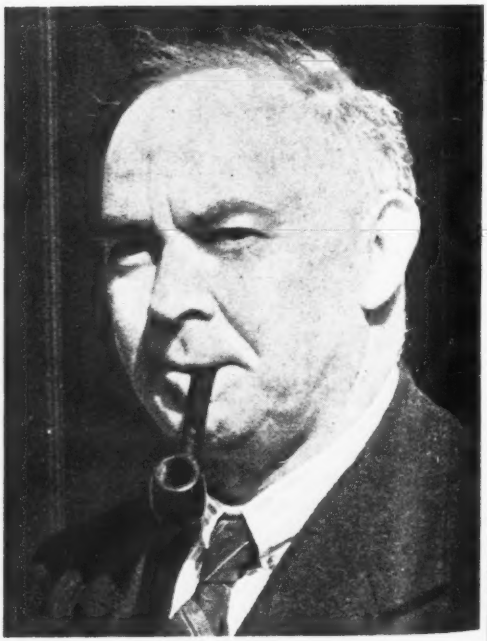
GOLD MEDALLIST

Professor L. Bairstow, C.B.E., F. R. S., A. R. C. S., F. I. Ae. S., Honorary Fellow, the tenth person to be so honoured, was awarded the Gold Medal of the Society for 1945. The presentation was made on the 30th May, 1946.

34th WILBUR WRIGHT MEMORIAL LECTURER

Mr. Ernest F. Relf, C.B.E., A.R.C.S., F.R.S., Fellow, gave the 34th Wilbur Wright Memorial Lecture on the 30th May, 1946. His paper was entitled "Recent Aerodynamic Developments."



THE ROYAL AERONAUTICAL SOCIETY

34th WILBUR WRIGHT MEMORIAL LECTURE

RECENT AERODYNAMIC DEVELOPMENTS

by

ERNEST F. RELF, C.B.E., A.R.C.S., F.R S., Fellow

Mr. Relf joined the scientific staff of the Aerodynamics Department of the National Physical Laboratory in 1912. *He has done research work in all branches of aerodynamics and was Superintendent of the Department for many years until his appointment early in* 1946 *as Principal of the new College of Aeronautics at Cranfield.*

THE THIRTY-FOURTH Wilbur Wright Memorial Lecture was delivered before the Society by Mr. Ernest F. Relf on Thursday, 30th May, 1946, at six p.m., in the Lecture Hall of the Institution of Civil Engineers, Great George Street, S.W.1. The chair was taken by Sir Frederick Handley Page, C.B.E., President of the Society.

THE PRESIDENT: Before calling upon the lecturer, he had another important and pleasant duty to perform, namely, to present the Society's Gold Medal, the highest honour the Society could bestow, and a distinction which had only been awarded on eight occasions in the long history of the Society.

This award of the Gold Medal had unanimously been made by the Council to Professor Leonard Bairstow, an Honorary Fellow of the Society, Fellow of the Royal Society and a Fellow of the Institute of Aeronautical Sciences.

Professor Bairstow had had a long and distinguished career in aviation, beginning with the Engineering Department of the National Physical Laboratory in 1904. He became Zaharoff Professor of Aviation at University of London, a post which he held for over 21 years.

Professor Bairstow's work on Aerodynamics was well known, by the publication of his book on the subject, his R. and M.s on stability, and for the papers he had read before the

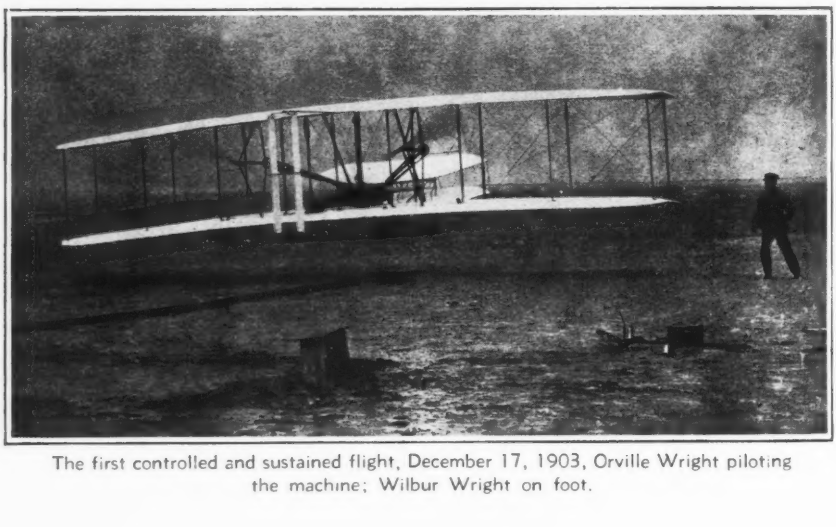
Society. Until recently he was Chairman of the important Committee which had been issuing data sheets on Aerodynamics on behalf of the Society. He had been a member of the Advisory Committee for Aeronautics for many years.

As President he had very great pleasure indeed in presenting to Professor Bairstow, on behalf of all members of the Society, the Gold Medal for his great and long continued contribution to aviation.

(The presentation of the Gold Medal to Professor Bairstow was accompanied by long applause.)

As was customary on the occasion of the Wilbur Wright Memorial Lecture, as President, he had cabled Orville Wright as follows:—

" On behalf of the Council and all members of the Royal Aeronautical Society, I send to you our very special greetings on the occasion of the reading of the 34th Wilbur Wright



The first controlled and sustained flight, December 17, 1903, Orville Wright piloting the machine; Wilbur Wright on foot.

Memorial Lecture, the first peace-time lecture for six years. The lecturer, Mr. Relf, will deal with the latest Aerodynamic problems and the results of research in the most modern wind tunnels. We all recall the astonishing results which you and your distinguished brother obtained from your own small wind tunnel, and your own painstaking researches

before accomplishing those first flights in December 1903 which have changed the face of the world. We look forward with confidence to an increasing use of the Aeroplane to bring ultimate peace and happiness to mankind."

He had received the following reply:—

Cordial greetings to officers and members of the Royal Aeronautical Society assembled. My earnest hope is that in our important research to perfect the aeroplane we do not forget to work assiduously to perfect the peace so that the aeroplane never again may be used as an instrument of destruction.

ORVILLE WRIGHT.

He had also received the following cable from the Institute of Aeronautical Sciences:—

The President, Officers, and Members, of the Council of the Institute of Aeronautical Sciences appreciate the greetings of the Royal Aeronautical Society on the occasion of the reading of the Thirty-Fourth Wilbur Wright Memorial Lecture, an occasion which further strengthens the bonds of common interest on both sides of the Atlantic.

PAUL JOHNSTON, *Director*.

He now had great pleasure in introducing Mr. E. F. Relf, a Fellow of the Society, who was to read the 34th Wilbur Wright Memorial Lecture. Mr. Relf was an old personal friend who had joined the scientific staff of the Aerodynamics Department of the National Physical Laboratory in 1912. He had carried out research work in all branches of aerodynamics and for many years was Superintendent of the Department. Recently, as most people knew, he had been appointed as Principal of the new College of Aeronautics at Cranfield.

He did not propose to anticipate what the lecturer had to say, but he felt he might be allowed to quote two things Mr. Relf said in which he was sure all would be in agreement; "I do not believe there was ever a period in aeronautical history so bright with the possibility of future progress" and "I would be so bold as to suggest we ought greatly to increase our research facilities. If we do not provide such apparatus, and that quickly, we shall lose a great opportunity for British Aeronautical Science."

To this he might be allowed to add that they must maintain their engineering research on an adequate scale so that they and not others could take full advantage of the developments from research in every practical application for every day use.

He had much pleasure in calling on Mr. Relf to deliver his lecture.

INTRODUCTION.

IT was with the greatest pleasure that I accepted the invitation of the Council to deliver the Wilbur Wright Lecture this year. Not that I count myself worthy to follow in the footsteps of the many illustrious men, British and American, who have delivered it in the past, but rather that I feel we are on the verge of discoveries and advances almost as spectacular as that flight of Orville Wright's, forty-three years ago, and that my peculiar experience may enable me to present to you some of the results of recent researches which have led me to the above somewhat prophetic conclusion.

During the war period there has very naturally been a tendency to reduce effort on fundamental research in order to be able to devote more time to matters of the moment, but we were wise enough not to cease doing fundamental work altogether, since we realised that at any moment it might show the way to advances of immediate practical importance in the prosecution of the war. It is perhaps because of this wise decision that the war years have produced some new ideas and discoveries that bid fair to open up revolutionary lines of progress in aeronautics. Some of these new ideas are still veiled in secrecy, but the veil has now been lifted at least sufficiently to enable me to draw on some very interesting material for the purpose of this lecture. For that I am especially thankful to Sir Ben Lockspeiser, who has done all that he could to leave me as free as possible to talk about matters hitherto regarded as confidential.

I propose, then, to discuss in turn several lines of recent thought and experiment in aerodynamics which seem to me to be pregnant with possibilities for the future. I shall not go deeply into the detail of them, for any one could provide enough material for several lectures, but shall rather try to sketch broad outlines and principles, and to show how, in my own opinion, these new ideas are likely to react on the progress of aviation. I think it is fair to say that although aerodynamic research has always been full of interest, and even excitement, there never has been a time in which so many spectacular possibilities have been displayed before our eyes. I say "possibilities" advisedly, because, for the most part, the new ideas have not yet reached fruition, and there is still much to learn about them before they can do so. Nevertheless, the broad principles are understood and the way seems clear; it is only a question of nurturing the good seed until the harvest is ultimately reaped.

THE "LAMINAR-FLOW" STORY

When I had the honour to give the James Forrest lecture in 1936 I made this remark: "The revolutionary discovery we need as regards surface friction is to find a means to make the boundary-layer flow remain laminar over a much greater proportion of the surface, or in other words, to prevent turbulence from developing in the boundary layer itself. If this were possible, the drag of bodies at very high Reynolds numbers would be reduced to about 10 per cent. of the values to which we are accustomed. The prospect appears so bright that one is inclined to assume *a priori* that there must be a physical impossibility in its achievement, but I do not believe it is possible to prove that this is the case."

Not I, nor anyone else, could at that time imagine how this retention of laminar flow was to be achieved, but we now know that the underlying principle is simplicity itself, as is often the case with fundamental new discoveries. Although we cannot yet see the way to reduce drag to the mere 10 per cent. of *complete* laminar flow, we can clearly see how to attain very substantial reductions.

The basic principle involved here is that there is no tendency for laminar boundary layer flow to break down into turbulence as long as the flow outside the boundary layer is accelerating, that is as long as the pressure gradient in the direction of the flow is negative, provided also that there are no violent disturbances of an external nature such as those due to turbulence in the fluid itself. It is therefore only necessary to ensure that the point of maximum suction shall be as far back as possible along the chord of a wing or the length of a streamline body in order to retain a laminar boundary layer at least up to that point. The development of the so-called "laminar flow" or "low drag" wings has been the search for sections which comply with the above requirement without making too great sacrifices in other desirable qualities, such as maximum lift.

There was some experimental indication of this possibility at least as long ago as 1939 but the significance of the result was not grasped. A test of an aerofoil designed by Dr. Piercy, having its maximum thickness at 40 per cent. of the chord, was made in the compressed air tunnel at the National Physical Laboratory. It showed considerably lower drag than that of previous aerofoils at low Reynolds numbers, but at high Reynolds numbers there was no gain. The drag curves are shown in Fig. 1. We now know that these effects were due to a more extensive laminar boundary layer, which, however, could not be maintained at high Reynolds numbers because of the high tunnel turbulence.

The true position was first grasped by our American friends, who realised the importance of experimenting in a very steady airstream and proceeded to design a wind tunnel with as low a degree of turbulence as possible. In this they tested many aerofoils designed to have a rising velocity along the greater part of the chord, and the results definitely proved the possibility of extensive

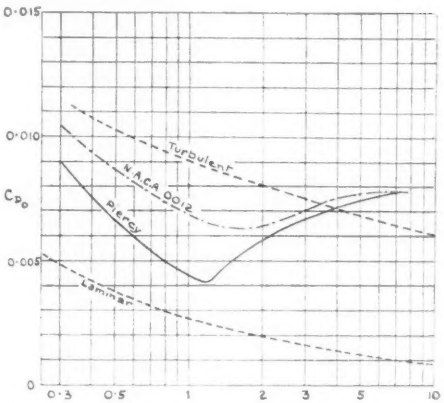


Fig. 1

Drag Curves of Piercy Aerofoil in C.A.T. showing evidence of Laminar Flow at low Reynolds number.

laminar boundary layers, even at the Reynolds numbers of flight. At the time we, in this country, heard rumours of curiously shaped wings with cusped trailing edges, and wondered what it all meant. This was early in the war, before the later excellent arrangements for interchange of information had been made. Before long we began to experiment for ourselves, not at first in a wind tunnel, but by mathematical means.

The development of these means was largely the result of the efforts of Professor S. Goldstein, F.R.S., who was working at the National Physical Laboratory during the war. He thoroughly explored the available methods for calculating the velocity distribution on a two-dimensional body and soon discovered good approximations to the reverse process of calculating the shape which would give a specified velocity distribution. This at once led to the design of aerofoils having a nearly linear increase of velocity from a point quite near the nose back to the point of maximum suction, which latter could be arranged to lie at any desired point along the chord. It was thus that the first British family of laminar flow aerofoils was born of pure potential theory,

afterwards to be tested in the only tunnel we had that was at all suitable for the purpose, and rather a poor one at that compared with its American counterpart.

The first successful experiment in this country was, however, made before the theory had been developed. Realising that an elliptic cylinder has its maximum suction at half-chord, an aerofoil was designed, the front 60 per cent. of which was elliptic while the back 40 per cent. was a cubic curve arranged so as to join the ellipse smoothly and to give a sharp trailing edge. The results of a test of this aerofoil in the 13 ft. x 9 ft. tunnel of the N.P.L. are shown in Fig. 2, mainly for their historic interest. It is seen that the lowest drag coefficient obtained was 0.0029 at a Reynolds number of 5×10^6, but that at higher Reynolds numbers the tunnel was not "good enough" as regards low turbulence, and the drag rose rapidly to the usual value somewhere near that of the flat plate with turbulent boundary layer.

Let us now look quite briefly at the nature of the aerodynamic properties of a typical laminar-flow aerofoil. The velocity distribution curves in Fig. 3 show the great difference between the new wings and the older conventional type; the points of transition to turbulent flow are marked approximately by crosses on the curves. These curves relate to the normal operating incidence, say, at cruising speed. The laminar flow aerofoil is designed so that at its most usual lift coefficient there is an equal

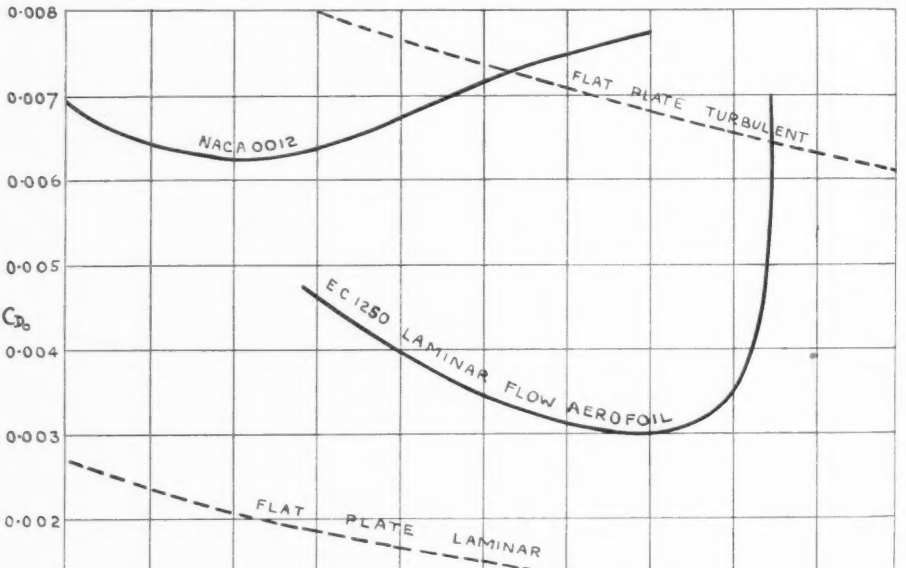


Fig. 2

Test of Aerofoil E.C.1250 in the 13' x 9' N.P.L. Tunnel, the first British test giving Low Drag at a fairly high Reynolds number.

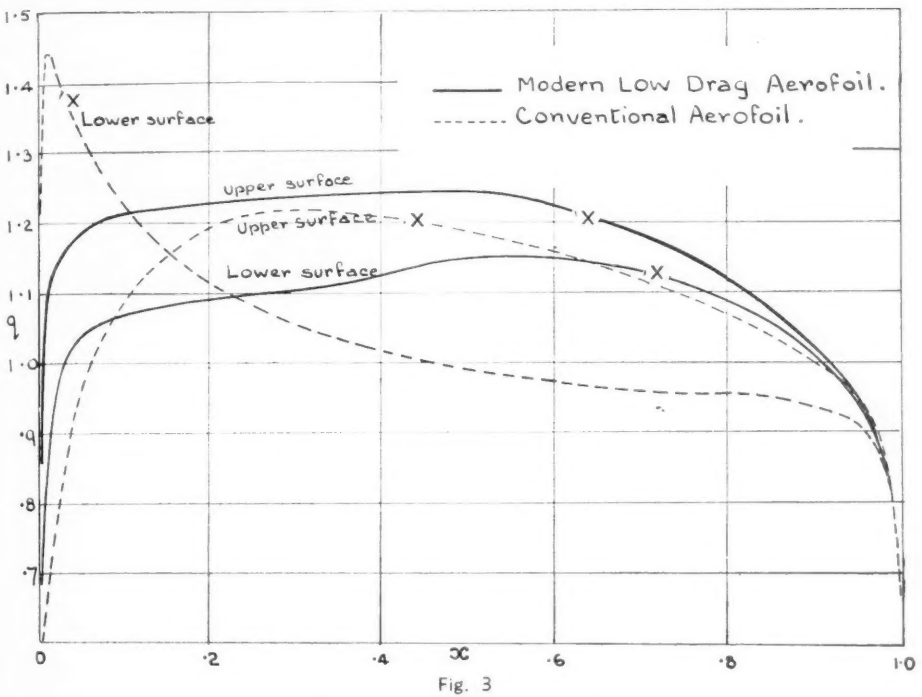


Fig. 3

Operating Lift Coefficient of 0.2.
Comparison of Velocity Distribution on a Conventional and a Laminar Flow Aerofoil.

favourable velocity gradient on the two surfaces.

The effect of departure from this design incidence is indicated in Fig. 4; increase of incidence reduces the favourable gradient on the upper surface and increases it on the lower. Soon the upper surface gradient becomes zero and then an unfavourable gradient develops near the leading edge, causing transition to move rapidly forward with a consequent increase in drag. Reducing incidence from the optimum design value produces the same sequence of events, but this time on the lower surface. The result is to give a drag curve against lift coefficient, like that depicted in Fig. 5, having a marked depression over a certain range of lift coefficient. Outside this range the drag behaves very much like that of the older aerofoils.

This range of lift over which low drag is attainable is one of the parameters at the disposal of the designer, and it is evidently roughly true that the larger he makes the favourable pressure gradient at the optimum incidence, the wider will be the lift range for low drag. There are, however, limits to the extent of the lift range, and in most practical sections it extends over about 0.3 or 0.4 in lift coefficient. American tests have shown that by use of a plain hinged flap at the trailing edge the optimum incidence can be considerably varied, and that it is possible, by suitably varying the flap angle, to get the low drag property over a lift coefficient range as wide as from zero to unity.

There is a limitation on the thickness of these new wings. Since the maximum suction now occurs much farther back on the chord than was the case with conven-

tional sections it is evident that the unfavourable pressure gradient on the rear part must have increased, since the pressure at the trailing edge will always be much the same. Hence there is a greater tendency for turbulent boundary layer separation to occur near the trailing edge. The American investigators have described a wing which is free from such separation as "conservative," and have shown experimentally that the greatest thickness-chord ratio permitting such conservatism is a little over 20 per cent.

Another important characteristic is the maximum lift coefficient. Laminar flow wings tend to be more pointed at the leading edge than the older wings and so there is a tendency for the maximum lift to be lower. It has recently been found possible, however, to modify the curvature near the leading edge so that little is lost in maximum lift, without seriously affecting the low-drag behaviour at normal incidence. This result was obtained by an extension of the theoretical method of designing such sections.

The most striking demonstration of the possibilities of these new sections in actual flight comes from a test made at the Royal Aircraft Establishment on a Kingcobra fitted with a " sleeve " of low-drag section at a suitable point on the span. A drag coefficient of 0.0028 at a Reynolds number of 18 x 10^6 was observed, and so it was proved beyond doubt that the phenomenon was producible under practical conditions.

Such, then, are the broad characteristics of the new wings; why are they not in more common use to-day ? There are several answers to this question, but by far the most cogent is the fact that such wings are very difficult to construct with the requisite accuracy of contour. A very slight " wave " in the contour is sufficient to produce a local reversal of the pressing gradient and so to

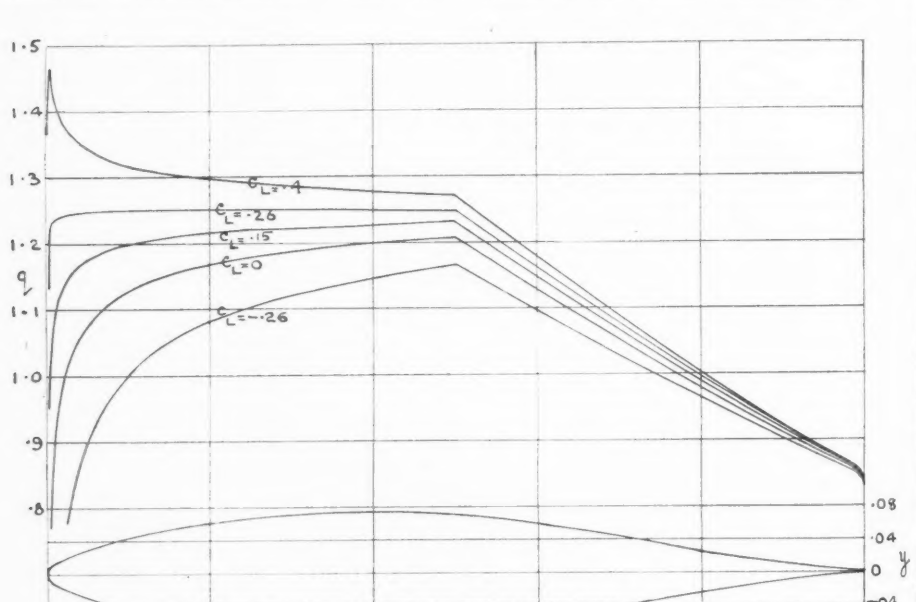


Fig. 4

Effect of Incidence on the Velocity Distribution of a Laminar Flow Aerofoil.

cause transition to turbulent flow. Experiment and theory have led to the conclusion that in waves a few inches in length the permissible height of the wave is no more than one thousandth of its length. This imposes an accuracy of construction on the designer of quite a different order from that to which he has been accustomed, and it is not too much to say that the success or failure of the laminar-flow principle depends almost entirely on the discovery of practicable methods of construction that will permit of the necessary accuracy of contour and maintain it under flight loads. A good deal of progress in this direction has already been made by our aircraft firms, but it can by no means be said that the problem is solved.

Another practical difficulty is the maintenance of the wing surface in a clean smooth condition. Very small specks of dust on a laminar-flow wing will upset the boundary layer locally and give rise to a wedge of turbulence behind the speck spreading at an included angle of nearly 20 degrees. Quite a small number of such specks, well distributed near the leading edge, can thus cause the flow to become mainly turbulent and so destroy the low-drag property of the wing. Flies caught on the wing during take-off and low flying are particularly troublesome in this respect. It may be necessary to protect the surface by means of a sheet of some thin material that can be torn off when the aircraft has climbed into "clean" air. Water-drops from a rainstorm will also spoil the low-drag behaviour, but this is only a temporary condition and the low drag is restored when the drops evaporate.

These effects of small excrescences have been rendered visible in flight by means of a simple and effective technique devised by W. E. Gray at the R.A.E. He painted the wing with a very thin coat of a liquid containing starch and potassium iodide and then flew through a cloud of chlorine produced

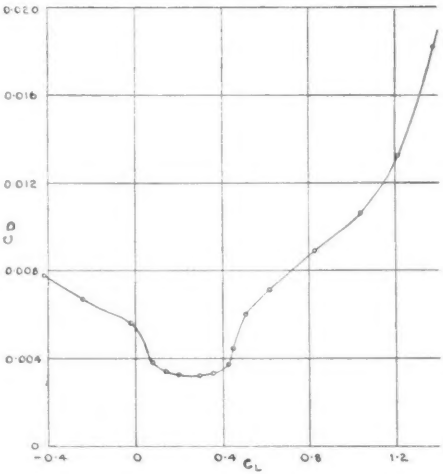


Fig. 5

Drag Curve of a Laminar Flow Aerofoil showing limitation of Lift Coefficient for Low Drag.

by introducing this gas into the exhaust of a chimney stack. The chemical action which resulted distinguished clearly between the laminar and turbulent parts of the boundary layer owing to the very different rates of diffusion on those parts.

An even more effective technique, though only suitable for use in the wind tunnel, has been subsequently developed at the N.P.L. The body to be studied is first sprayed with an emulsion containing china clay, which is allowed to dry, producing a very fine mat white surface. Before an experiment this is sprayed with nitro-benzine, whose refractive index is about the same as that of the china clay particles, with the result that the white appearance completely disappears. When the wind stream is applied the nitro-benzine evaporates much more quickly in the turbulent part of the boundary layer, where the momentum exchange with the free air is much more rapid than in the laminar part. In a few minutes all the turbulent part has become white again, while the laminar part remains unaffected. An example of the resulting picture is given

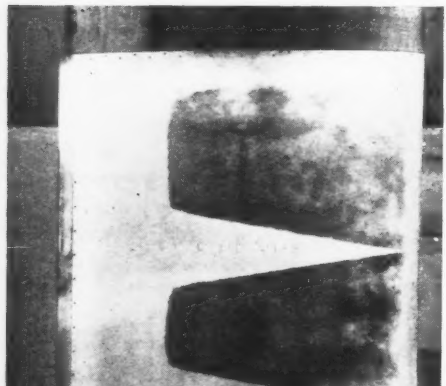


Fig. 6
Transition and Turbulence behind an excrescence shown by the "China-Clay" Technique.

in Fig. 6. The normal transition is clearly shown by the line of demarkation parallel to the wing span, while a single particle near the leading edge has produced its well-defined wedge of turbulence. This technique is invaluable in wind tunnel work, since it enables one to be sure that results are not being vitiated by unsuspected dust particles.

It may fairly be said, in summarising the present position on the laminar-flow problem, that the underlying theory is now well understood, that the experimental demonstration of its validity is complete, but that there still remains much to be done before realisation in practice becomes sure and certain. Certainty must be achieved before full advantage can be taken of the discovery, since a permanent failure of the laminar regime in the early stages of a flight would involve carrying the same fuel weight as if an ordinary wing had been used.

Similar reasoning can be, and has been applied to the design of streamline bodies with extensive laminar boundary layers, although, as far as I am aware, the resulting shapes have not yet been subjected to experiment. Like the aerofoils, they tend to have a marked cusp at the rear end. One can hardly help speculating as to whether the faster-swimming fishes have anticipated our discoveries, for they certainly have a form not unlike those which we have calculated!

BOUNDARY LAYER SUCTION

We now come to a new development in wings which is even more surprising at first sight than the laminar-flow wing, but which has not yet been explored to the same extent. The original idea was due to Dr. A. A. Griffith, F.R.S., who arrived at it when thinking of means of avoiding boundary layer separation in a diffuser. The basic idea is to design a shape for which there is a sudden discontinuity of velocity and pressure at one or more points and to apply boundary layer suction at these points.

The idea of using suction to modify boundary layer flow is a very old one, and hopes have been entertained of replacing turbulent layers by laminar ones in such a way. Some experiments in a pipe were made a long time ago at the R.A.E., and F. G. Miles tried a perforated wing surface with internal suction in flight, but neither of these experiments produced any spectacular result. The fact that suction could prevent turbulent boundary layer *separation* has long been known, and very great increases of maximum lift have been demonstrated experimentally both here and abroad. This use of boundary layer suction has recently been successfully employed in flight by the Armstrong Whitworth Aircraft Company to avoid premature tip stalling on a swept-back wing.

All these older experiments merely applied suction at some point on a wing of conventional form; the new idea started by Dr. Griffith was to *design the shape to suit the suction*. The application of his idea to the

design of wings was taken up at the N.P.L., and the extensive mathematical investigations of Dr. Goldstein and his successors, previously mentioned, proved of great value in attacking this new problem.

Let me try to put this basic idea in as simple a form as I can. The diagram in Fig. 7 shows two aerofoil shapes and their theoretical velocity distributions, and for simplicity we will consider symmetrical aerofoils at zero lift. The one at the top is a simple laminar flow aerofoil, while that below is what we now call, for brevity, a "suction aerofoil." In both cases there is a rising velocity up to a point well back on the chord, but whereas the ordinary aerofoil then exhibits a rapidly falling velocity up to the trailing edge, the suction aerofoil exhibits a large discontinuous fall of velocity followed by a gentle rising velocity from the position of the suction slot to the trailing edge.

The aerofoil shape was in fact obtained by *assuming* such a velocity distribution and applying the mathematical theory. Griffith's original idea was that as there is now an accelerating flow over the whole aerofoil surface, except just at the suction slot, it might be hoped that the whole boundary layer would remain laminar, with a resulting very low drag. Put in another way, the laminar layer on the front part was largely to be sucked away, and a new layer started at the stagnation point which must occur just behind the slot. Since the velocity gradient is favourable this new boundary layer should remain laminar right to the trailing edge.

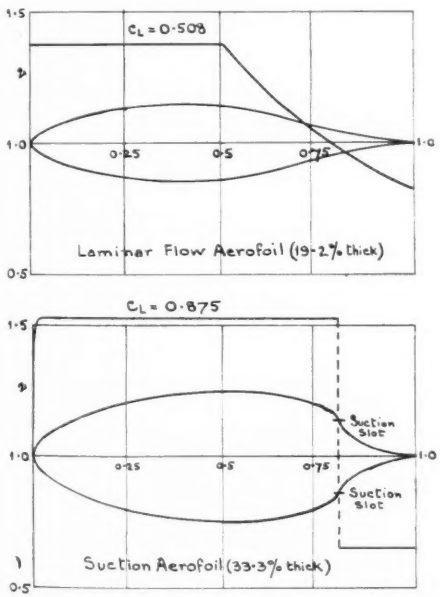


Fig. 7
Comparison of Shape and Velocity Distribution for a Laminar Flow and a Suction Aerofoil.

A model was made and tested at the N.P.L. The effect of the suction was first observed by attaching fine silk threads to the surface and it was very interesting to see how those behind the slot, which were almost invisible owing to the violent disturbance there when the suction was not applied, became suddenly steady when the suction reached the requisite amount. The state of the boundary layer was indicated by allowing a fine stream of dense oil smoke to issue from small holes in the model. It was at once noted that the flow on the part behind the slot was only laminar for a very short distance from the slot and then became turbulent.

Various causes for this were suspected, such as vibration of the thin lip of the slot and pulsations from the air-pump, but it soon became evident that none of these was the cause, and that there was something wrong with the assumption that the flow ought to be laminar. It was then remembered that Görther had studied theoretically the flow on concave surfaces and shown the conditions under which laminar flow became unstable on them. His theoretical criterion fitted the N.P.L. experimental observations and so it became evident that complete laminar flow to the trailing edge, as envisaged by Griffith, was probably impossible of attainment.

Nevertheless, the suction principle still has great attractions, one of which is that it enables very thick sections to be used without fear of any turbulent separation and probably with a laminar boundary layer up to the slot. It is interesting to note that even if the boundary layer is turbulent from the leading edge, separation near the slot is still prevented by using very little more suction than is needed for a laminar boundary layer. Thus, even foregoing all laminar flow, it becomes possible to make very thick sections, 40 per cent. or even 50 per cent. thick if need be, with drags of the same order as those of thin sections.

This fact may have a profound influence on the minimum size of " flying wing " that is a practical proposition from the point of view of internal space. Since in any thick wing the maximum velocity increment near the surface must be high, the critical Mach number is necessarily low, and such wings therefore only have an application to aircraft of moderate speed.

The mathematical theory had to be extended in order to deal with these very thick sections, since all the previous work of Goldstein was based on " thin aerofoil " theory and this approximation was no longer good enough. Lighthill bridged the gap by a new treatment in which he assumed a velocity distribution over the circle of transformation and from it deduced both the shape and the velocity distribution of the corresponding aerofoil. His treatment is exact and so there are no limitations on account of thickness, but it needs some experience in choosing such a velocity distribution on the circle as will lead to an aerofoil approximating to that required.

A good example of the application of this method is shown in Fig. 8, which depicts an aerofoil 38 per cent. thick with a single slot on the upper surface. This aerofoil is

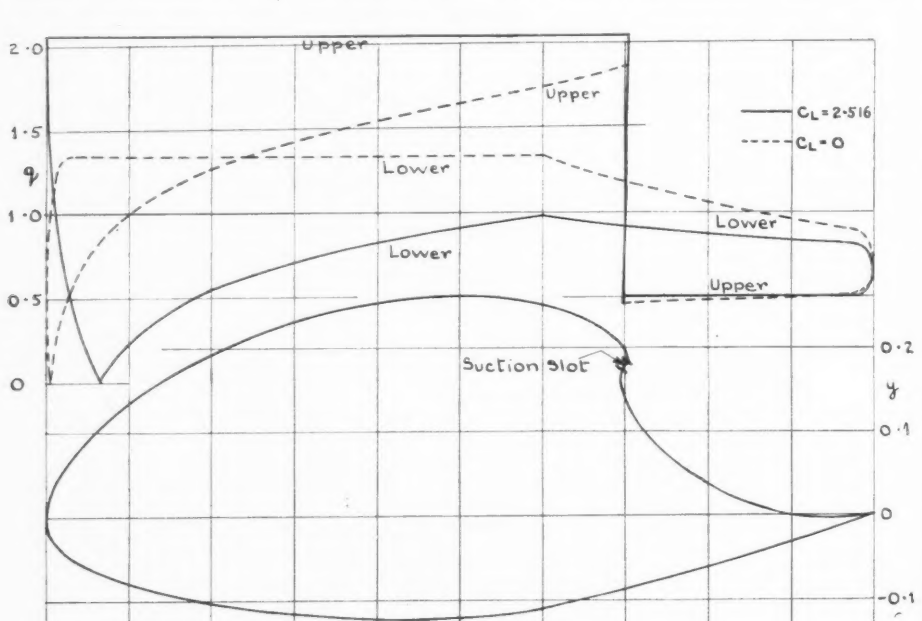


Fig. 8

Thick Suction Aerofoil with a Single Slot, $CM_0 = 0$, and a Lift Coefficient Range from 0 to 2·5.

now being constructed for test; theory indicates that it should have a lift coefficient range from zero to 2.5 without adverse velocity gradients.

It is instructive to consider how the effective drag on such an aerofoil is to be measured. If one uses the wake traverse method, all that is measured is the drag of the part behind the slot, for most of the "tired" air in the boundary layer of the forward part is sucked into the slot and so does not appear as a loss in the wake. If there were no sources of energy loss in the ducting and the pump were 100 per cent. efficient, one can visualise what happens in this way: the pump restores the total head lost in the forward part of the boundary layer and returns the air to the general stream with its original total head, thus doing an amount of work corresponding with the skin friction on the front part. The remainder of the drag energy due to the skin friction on the rear part appears in the wake loss. In a real case there must be added to these two drag components the losses in the ducting and in the pump, so that it is evident that to obtain the best possible result the duct losses must be kept as low as possible and the efficiency of the pump as high as possible.

In the few experiments so far made no special attention has been paid to these matters, the primary preoccupation having been to discover the best form and width of slot to use and the minimum amount of air that must be sucked away to achieve the desired end. Under good conditions it is only necessary to suck away about half the quantity of air in the boundary layer, but the slot needs to be very narrow and the rather high velocity just inside it may involve considerable internal losses. Moreover, such a very narrow slot might present great difficulties of practical manufacture. With a greater slot width the amount of air that has to be removed increases somewhat, but the lower slot velocities are easier to deal with internally. There is obviously a compromise here, and a great deal more detailed work will be needed before the best practical arrangement can be determined.

Another application of the suction principle is to the thin wings which are necessary at very high speeds of flight, including supersonic flight. These wings have of necessity a very poor maximum lift coefficient, little if any greater than that of a flat plate; about 0.9 for the plain wing and perhaps 1.3 or 1.4 with a flap. It appears, from theoretical considerations, that the maximum lift coefficient could be increased to a value in the neighbourhood of 2.0 by the use of a suction slot very close to the leading edge. Experimental verification of this prediction has not yet been attempted, but will be shortly. It may well be that the provision of ducts of sufficient size in so thin a wing will prove difficult or even impossible, but if it can be done one of the greatest defects of thin wings will have been overcome.

Once the use of suction is conceded as a practical possibility, there are certain other uses to which it might be put in the endeavour to improve the general aerodynamic characteristics of aircraft. Mention has already been made of its use to prevent tip stalling. Another possibility is its use to prevent incipient flow separation at points such as the junction of wing roots and fuselage in a conventional aeroplane. In other words, it may provide an effective alternative to filleting.

A more far-reaching development, which has hitherto been little explored, is the use of suction, instead of moveable surfaces, to provide aircraft controls. It is a little difficult to see how this is to be done at high speeds, but there is a good deal of evidence to suggest that such a scheme might be highly effective at stalling incidence, which is just where the conventional controls are most troublesome. There appears, in fact, to be a very wide field of possible suction

applications, which would well repay an extensive research on broad lines.

In any discussion of this problem, an inevitable question arises: what happens if the suction fails ? There are two ways of dealing with this; one is to design in such a way that suction failure would not prove catastrophic, the other is to make the probability of failure of the suction plant so small that it is a negligible risk. The former procedure may not prove to be so difficult as might at first be supposed. For example, when the first model of a suction wing was tested at the N.P.L. it was found that quite a reasonable amount of aileron control remained when the suction failed. There was, of course, a complete breakaway of the airflow in the neighbourhood of the slot, but it appeared that the flow rejoined the surface before the trailing edge was reached and so preserved some measure of aileron control. This wing, however, was only 16 per cent. in thickness-chord ratio, and it may well be doubted if a similar result would be obtained if the thickness were increased to, say, 30 per cent.

It is proposed to examine this particular aspect of suction failure by testing wings of appropriate shapes, but without suction, in the compressed air tunnel to determine their aerodynamic characteristics at a reasonably high Reynolds number.

Duplication of suction plant should provide increased reliability in very much the same ratio as does the use of more than one engine in the cognate problem of engine failure. Nevertheless, it seems undeniable that the better solution, if it is possible, is to retain enough control for emergency use when suction has failed. One has a fair chance of making a successful forced landing in the event of complete engine failure, but the thought of an aeroplane which loses all control as a result of the failure of a mechanical device is a very disquieting one, even if the probability of such a failure is extremely small.

The efficacy of blowing air from a slot, instead of sucking, as a means of boundary layer control has often been discussed. Blowing has considerable advantages over suction from the practical point of view because pressures *above* atmospheric are generally readily available in the main power plant of the aircraft, whereas pressures *below* atmospheric need additional mechanical accessories. Moreover, a combination of blowing and sucking looks attractive, since it might well enable a dual boundary layer control to be achieved locally by a local pump, and so avoid extensive ducting.

Very little experimental work has so far been done on boundary layer control by blowing air into the layer, and the problem is not nearly so amenable to theoretical treatment as the corresponding suction problem. Such experiments as have been made are disappointing and suggest that to achieve similar results a blowing device needs several times as much air as is needed with suction. It would, however, be a mistake to dismiss blowing as impracticable in the present state of knowledge. The mere fact that the necessary pressure might in some cases be forthcoming from "ram" effect, with small losses and without any additional mechanism, may well offset the lesser "volume efficiency" of the process.

Recently a still further means of suction control of the boundary layer has been under consideration at the N.P.L. This involves the use of distributed suction acting through a porous surface in place of local suction at one or more slots. Again the idea is not new, the possibility of using perforated surfaces having been suggested many times in the past. The flight experiment made by F. G. Miles mentioned previously is a case in point. What is new is the production of a porous material in the form of a sintered bronze which has interstices of extremely small size and very closely spaced. It appears quite likely that the use of such a material may lead to success where a surface

with comparatively widely spaced larger holes was a failure. Dr. Preston has been considering this boundary layer problem from the theoretical aspect, and is convinced that it holds out great promise. He is preparing to put his ideas to the test of experiment.

In summing up this part of my lecture I would say that control of the boundary layer by extraction or injection of air has long been known to lead to considerable modification of the aerodynamic behaviour of bodies, but that only in the past two or three years has it been suspected that developments of this kind which might radically affect aircraft design were possible. While the underlying principles are understood, the detail has not yet been worked out as far as it has in the case of the simple laminar-flow aerofoil, and there remains a great deal to be done before practical application could be undertaken with any certainty of success. I may say that steps are already in hand to try a "suction" wing in actual flight.

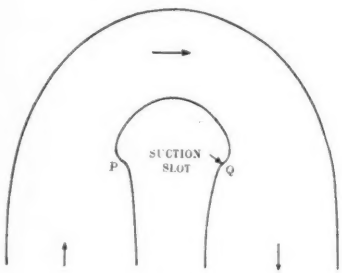


Fig. 9

Velocity 2.47 on PQ, and unity on all other parts of the boundary.

Bend of 180° in a Duct with a single Suction Slot.

As an example of the curious things which seem possible by the use of suction, I am tempted to show one other application suggested by theory; this time to the wind tunnel rather than to the aeroplane. Fig. 9 shows a 180° bend in a two-dimensional duct, designed by Lighthill, with suction at a single slot. According to the potential theory this should enable the air to turn the corner without any controlling cascade of aerofoils, as is usual in wind tunnel bends, and to maintain a uniform velocity distribution at the outlet. How far this astonishing result could be achieved in the presence of boundary layers and in a three-dimensional duct is not known, but it would seem well worth while to make the experiment.

THE QUEST FOR HIGHER SPEED

The recent developments in aerodynamics so far considered relate primarily to aeroplanes of moderate speed, and are endeavours to progress still further in the direction of drag reduction. I come now to very different aerodynamic phenomena which are concerned with the effects of the compressibility of the air when speeds become comparable with that of sound. I venture to refer once more to my James Forrest lecture of 1936. I said there that even if great improvements were made in power plants I doubted if very great speed increases would result, because of the exceedingly rapid rise of drag coefficient which occurs when the speed approaches that of sound. I even gave a very veiled hint that I thought 600 miles an hour was a likely limit.

Ten years later we have just reached that speed in horizontal flight, so the prophecy was not such a bad one. I would, however, not be so unwise as to repeat it to-day ! The enormous developments of the gas turbine and of rocket propulsion have put quite a different limit to what is possible in the way of speed, a limit which now appears more likely to be ultimately fixed by temperature rise than by aerodynamic drag or power plant thrust.

But I anticipate. Let us consider broadly what is known of aerodynamic phenomena when the compressibility of the air is the main factor, rather than its viscosity, say roughly at speeds greater than seven-tenths

of that of sound. Since the problems of aerodynamics at speeds well in excess of that of sound are in some respects much simpler than those quite near the sonic speed, whether above or below, I propose to say a little about " supersonic " aerodynamics first, and then to return to the so-called " transonic " region, which presents the most difficult problem of all.

AERODYNAMICS OF SUPERSONIC FLIGHT

The advent of the jet engine and the development of rocket propulsion have made flight at speeds above that of sound quite feasible, and so have awakened great interest in supersonic aerodynamics. Quite a lot was known in this field before anyone thought that supersonic flight was a practical possibility. Thus the drag of projectiles had been studied for many years by those interested in external ballistics and it was well known that the drag coefficient experiences a very rapid rise near the speed of sound, but that well above that speed it falls again gradually.

Many years ago Sir Thomas Stanton made a three-inch supersonic wind tunnel at the N.P.L. and was able to correlate the results of tests of tiny model bullets with those of firing tests on artillery ranges. He also tested aerofoils in his tunnel, even to the extent of determining the pressure distribution over model aerofoils of only half an inch chord. About this time Ackeret stated the theory of thin sharp-edged supersonic aerofoils now generally known by his name, and G. I. Taylor restated it for the benefit of English-speaking readers and compared its predictions with Stanton's experimental results.

This theory is a first approximation to the solution of the full equations of flow and has proved to be a very good approximation for thin aerofoils provided the Mach number is well above unity. It is exceedingly simple, amounting merely to the statement that the pressure at any point on the aerofoil surface is proportional to the angle between the tangent at that point and the direction of motion, the constant of proportionality being a function of the Mach number only.

A number of important deductions follow at once. The lift coefficient is proportional to the angle of incidence and is independent of the shape of the aerofoil. Thus camber has no effect at all on lift, in marked contradistinction to its effect at low speeds. The lift slope decreases as the Mach number increases. The centre of pressure is at the half-chord instead of approximately at the quarter-chord point. The drag coefficient depends on the integral round the contour of the square of the angle between the tangent and the direction of motion, and it follows that for similar shapes the drag coefficient at zero lift decreases as the square of the thickness-chord ratio instead of being nearly independent of this ratio as it is at low speeds. The best shape for a given thickness is a double wedge, whose drag is three-fourths of that of a bi-convex section formed of circular arcs. The maximum lift-drag ratio of the double wedge (neglecting skin friction drag) is equal to half the reciprocal of the thickness-chord ratio, and occurs when the front part of the upper surface is exactly along wind, that is, when the angle of incidence is equal to half the angle of the wedge. Thus a section of 5 per cent. thickness has a maximum lift-drag ratio of 10, and it is at once evident that the supersonic aerofoil, if sufficiently thin, can provide aerodynamic efficiencies of at any rate the same order as those to which we are accustomed at low flight speeds.

Further development of the theory of supersonic flow round an aerofoil brings to light other marked differences from the low-speed subsonic behaviour. It appears that aspect ratio is of much less importance in supersonic flight, and that quite small aspect ratios, of the order of unity, can be used without serious drag being encountered.

Another important fact is that the customary downwash directly behind the aerofoil has almost disappeared, the air having downward momentum to balance the lift being only that confined between the shock waves springing from the leading and trailing edges. If we imagine a conventional aircraft with a tailplane, both the recession of the centre of pressure to the half-chord point and the removal of the downwash at the tail tend to make the aeroplane more stable in supersonic flight than at low speeds.

We are also able to learn something about control characteristics. Thus the simple Ackeret theory tells us that the ratio of the lift change due to unit control angle, to that due to unit incidence change is merely the ratio of control chord to wing chord. We thus find that the behaviour of control surfaces of the conventional kind is of the same nature and the same order of magnitude as in low speed motion.

The drag coefficient of fine pointed bodies of revolution has been studied theoretically, notably by Lighthill. Here we are not on such secure ground as in the corresponding two-dimensional problem of the thin wing, as there is evidence from experiment that the boundary layer separates from the surface on the tapering tail-end of the body. If it did not separate, the drag coefficient expressed on projected frontal area would, for the best shapes, be about ten times the square of the reciprocal of the fineness ratio and to this approximation is independent of the Mach number. If we take, very roughly, a fineness ratio of ten, and a wing area ten times that of the maximum cross-section of the body, the body drag comes out about equal to that of a 5 per cent. thick wing at zero lift at a Mach number of 1.4.

The outcome of all this elementary and somewhat sketchy reasoning is that the aerodynamic behaviour of an aircraft of conventional lay-out, but with a considerably thinner wing than usual, is not in any way strikingly different at supersonic speeds from what it is at speeds of to-day. In other words, there is no fundamentally different feature in the aerodynamic behaviour which suggests any major difficulty in flight at supersonic speeds. The aerodynamic problems involved are, in fact, simpler than those at sub-sonic speeds, and sufficient information exists to enable a reasonable design to be elaborated. It is not pretended that such a design would closely approach the best possible for a supersonic aircraft; the point is merely that given sufficient thrust from the propulsive mechanism, there seems to be no aerodynamic reason why a successful supersonic aircraft should not be achieved very soon.

The theory of supersonic flow has been developed considerably beyond the simple concepts I have just stated. Some of this development is quite old, such, for instance as the Prandtl-Meyer theory of expansion round a corner, the work of Taylor and Maccoll on the flow around a circular cone, and that of Büsemann on flow around aerofoils, including his special form of biplane which should have no shock wave drag at one particular Mach number. These theories have been considerably extended in recent years and have provided a fairly complete statement of the supersonic flow around simple shapes like the thin aerofoil and the pointed body. They have also shown exactly what are the limitations and degrees of approximation of the simpler theories, such as that of Ackeret for thin aerofoils.

Experimental verifications of the theoretical predictions are rather scanty, especially with regard to the behaviour of aerofoils of finite span, mainly on account of the lack of supersonic wind tunnels of reasonable size. There are only two such tunnels in this country and neither of them has been in use for very long. One is the eleven-inch continuous-flow tunnel in the Engineering Division of the N.P.L., which has been mainly used for work on projectiles, while the other is a one-foot injector-type tunnel in the Aerodynamics Division. This latter is the original high-

speed tunnel running on the compressed air supply of the N.P.L. compressed air tunnel, and provided with supersonic effusers in place of the original parallel intake. It has been used, in its supersonic form, for a preliminary study of the characteristics of two-dimensional aerofoils, and an example of the results is given in Fig. 10.

This diagram exhibits the lift and drag characteristics of a double-wedge aerofoil and a comparison with the deductions from the simple Ackeret theory, which is shown to be a very good approximation when the Mach number exceeds about 1.2. In the drag diagram an allowance has been made for skin friction, which is, of course, absent from the theoretical prediction.

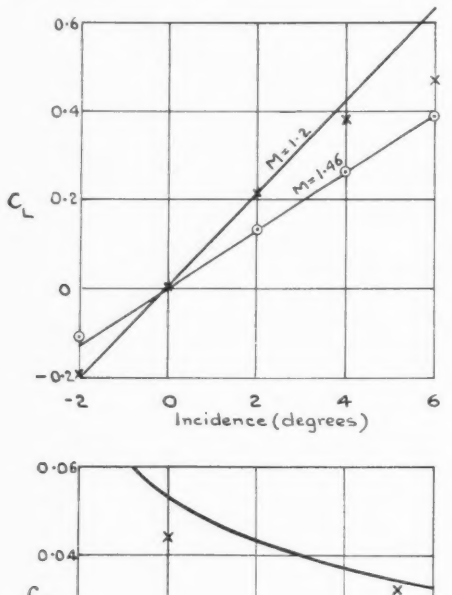


Fig. 10

Lift and Drag of Double-wedge Supersonic Aerofoil compared with Ackeret's Theory.

A smaller induced flow tunnel at the N.P.L. has been used to obtain photographs of shock waves, and an example is given in Fig. 11 which shows clearly the strong shocks from the leading and trailing edges and gives some indication of the expansion round the obtuse angle at half-chord. This picture was taken at a Mach number of about 1.4.

No serious experimental work has yet been done on three-dimensional models, such as those of complete aircraft. A larger tunnel is badly needed for such work, and the development of the experimental technique will take some time, not the least difficult point being the method of supporting the model without undue interference with the flow around it. The eleven-inch tunnel mentioned above has recently been used to determine the pressure distribution on short aerofoils mounted on one wall and has so provided some experimental data on the effects of aspect ratio.

These various experiments really only amount to a little skirmishing on the fringes of the subject of supersonic aerodynamics; we are, in fact, much in the same position with regard to the subject as we were about the year 1912 with regard to low-speed aerodynamics, but with one important difference: we have, in the supersonic field, a well-developed theory. We may be very thankful for this; it will help us along the right path until we can build experimental equipment to study those problems which arise in practice and are usually too complex for theoretical treatment in detail. One such is the whole question of skin friction in supersonic flow, or, in other words, the relative importance of Mach number and Reynolds number in defining aerodynamic behaviour. Even here we have already some indications, and we shall not be far wrong if we assume the ordinary low speed skin-friction laws to be true and add the drag they predict to that arising from the shock-wave system.

What will the supersonic aircraft of the future look like? This is not an easy question to answer, but some trends are fairly

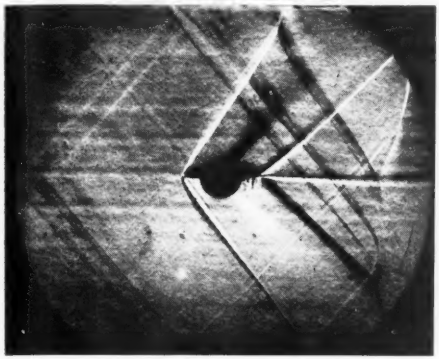


Fig. 11
Shock Wave System of a Supersonic Aerofoil.

apparent. It will certainly have very thin wings, and if it has a body at all, in the conventional sense, that body will be as long and thin as it can conveniently be made. In fact, " thinness " seems to be the key to low supersonic drag.

The aspect ratio will probably be quite low, though whether the wings will be heavily swept-back or not is at present a moot point; we do not know enough to predict with any certainty. I shall have more to say on the effect of sweep-back when I come to consider very high subsonic speeds, where this effect seems likely to be definitely beneficial. The problem, in short, will be to obtain enough stowage space without sacrificing the slim lines that are necessary for reasonably low drag. It would seem that the very small supersonic aircraft will present a particularly difficult problem for this reason, unless its endurance is very short indeed, as may well be the case for aircraft built primarily for experimental work.

Whatever form the supersonic aircraft ultimately takes, it will almost certainly differ greatly from that of present-day machines, and one problem which will arise is that of control at low speeds during take-off and landing. I have already suggested that boundary layer suction may provide the key to the attainment of sufficient lift on thin wings, but the control problem may prove very difficult if the aspect ratio is very low.

Fortunately we have the means to study this point in our present large low-speed wind tunnels, and it would be of much interest now to carry out low-speed experiments on the unconventional forms that appear likely to be suitable for supersonic flight in order to see if their low-speed control problems can be satisfactorily solved. The point is an important one since the maximum lift coefficient attainable *with full control* will settle the supersonic operating conditions to a great extent. A little arithmetic shows that if the aircraft is to fly at an incidence near that at which its lift-drag ratio is a maximum, either the wing loading must be considerably higher than present-day figures or else the operating altitude must be much greater. The former alternative makes the landing problem more difficult while the latter has obvious difficulties relating to pressure cabins and engine performance.

Perhaps it is too early even to speculate on such things: the first problem is to get off the ground and attain supersonic speed. When that has been done, and we have experience of the new conditions of flight, we shall be more ready to face the detailed question of how to design the best form of supersonic machine and how to specify its best operating conditions. This brings me naturally to what is probably the most difficult problem aerodynamicists have yet had to face: what happens in the so-called "transonic" region, in the immediate neighbourhood of the speed of sound?

THE TRANSONIC REGION

In recent years much information has been accumulated on aerodynamic behaviour at high subsonic speeds. The necessity for this was forced upon us by the ever-increasing speeds of aircraft, for although until very recently aircraft could not fly *horizontally* at speeds high enough to make compressibility effects important, they could and did dive at such speeds, and troubles that were

met, particularly with the controls, made it imperative to study the phenomena involved.

To our American friends belongs the honour of constructing the first wind tunnel for the purpose; the eleven-inch induced flow high speed tunnel at Langley Field. This apparatus was copied in England when we built the twelve-inch high speed tunnel at the N.P.L. to which I have already referred. Then came the two-foot tunnel at Langley, the eight-foot direct drive tunnel at the same Laboratory, the twenty-by-eight inch flexible walled tunnel at N.P.L., and the ten-by-seven foot high speed tunnel at the R.A.E. This last tunnel had the additional feature that the air pressure in it could be widely varied.

In these tunnels the behaviour of aerofoils and complete models has been studied intensively and the results have added enormously to our understanding of high speed aerodynamic phenomena. Most of the basic facts are now so well known that I need not describe them in any detail. Suffice it to mention that at a given incidence the lift coefficient increases at first with the Mach number, but later falls abruptly; the drag coefficient remains nearly constant at first but above a certain Mach number, dependent mainly on " thickness," rises very rapidly, while the pitching moment can exhibit a variety of behaviours varying from almost complete insensitivity to very violent changes in either direction depending on the wing shape, wing camber and relative positions of wing and tail plane. Any of the more violent changes occur at a Mach number somewhat greater than the so-called critical Mach number which is that at which the local speed of sound is first reached at some point in the field of flow, usually near the point of maximum suction on the wing.

This leads to the general conclusion, well borne out in practice, that no trouble is likely to be experienced from compressibility effects as long as the speed of flight is below that corresponding to the critical Mach number. Since the increment of velocity when the air flows round a body is least when the body is thin, we should expect " thinness " to be good for high subsonic speeds, just as we have seen that it is at supersonic speeds.

This expectation is realised in practice: for example, the Spitfire is one of the few aircraft that have given no trouble in fast dives, and it is a particularly " thin " aircraft. But the matter cannot be dismissed as simply as this; the more nearly we approach the sonic speed the more likely we are to encounter difficulties, and the greater is our ignorance of the precise nature of those difficulties.

One reason for ignorance is that it is not possible effectively to use the wind tunnel to acquire knowledge in this region. High speed tunnels can be used up to a Mach number of about 0.85 but if we attempt to go higher, they " choke," as we say. This means that the Mach number in the neighbourhood of the model rapidly increases to unity and a shock wave extends right across the air stream. The reason for this behaviour is not far to seek.

If the relation between the Mach number and the cross-sectional area of a stream-tube is calculated, it is found that near a Mach number of unity the area varies exceedingly slowly. Thus, for the 10 per cent. change of Mach number from 0.9 to 1.0, the change of area of the stream tube is only 0.9 per cent. The flow is thus in a very critical state when the speed is close to that of sound.

Even if an empty tunnel could be persuaded to run at, say, $M = 0.95$, the introduction of even a very small model would choke it, because of the change of cross-sectional area of the stream brought about by the model. As Dr. Hilton graphically puts it, the size of the model that can be used shrinks to zero as the speed reaches the sonic speed and then grows again as the speed increases above that of sound. Hence the wind tunnel is of little use in a range of Mach number from about 0.85 to 1.15. Yet we must fly through this range if we are to attain supersonic speeds and so

we must seek means of investigating aerodynamic behaviour in this range.

The obvious answer is to move the model through the air, instead of blowing an air current over the model. One way of doing this is to drop heavy bodies from a great height and to make observations on them by means of internal instruments communicating with the ground by radio or salved after the fall, or by external observation such as is provided by radar tracking. This line of attack is being explored and some few observations have already been obtained.

A second way is to project a model through the air by means of a rocket and to use similar methods of observation. This also is being developed.

The last way is by flight itself, but it is evidently unwise to proceed far in this direction, on account of possible unexpected dangers, until something has been learned by the use of pilot-less models. The second method is, of course, precisely that used in ballistics and it is significant that the drag of shells is the only aerodynamic quantity which has hitherto been measured accurately over the whole range of speed from zero to more than three times that of sound.

I have already said that we know a good deal about aerodynamic phenomena at speeds well above that of sound. It is instructive to see how much we can guess of what will happen close to that speed from our knowledge of what happens well below and well above it. I have prepared three diagrams to illustrate this point.

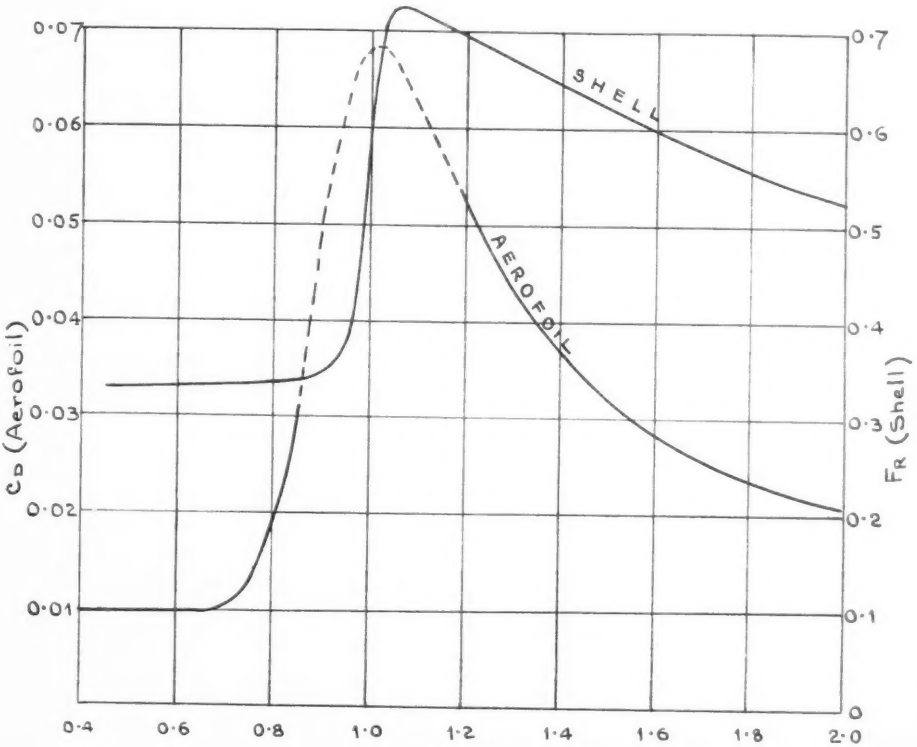


Fig. 12

Drag Curves of Supersonic Aerofoil and Shell.

In the first of these, Fig. 12, we have the drag curve of a typical supersonic aerofoil over the whole range of speeds for which it is known, there being a gap between the Mach numbers of approximately 0.8 and 1.2. On the same figure is shown the established drag curve for shells. It is evident that we can make a very reasonable guess as to how the aerofoil drag curve will behave in the unknown region near the sonic speed; the dotted part of the curve is my own guess.

But if we plot the slope of the lift curve instead of the drag, as is done in Fig. 13, we find that guessing is quite out of the question, nor have we in this case any rough guide from ballistic experiments.

In Fig. 14 I have shown the elevator angle to trim as a function of Mach number for two aeroplanes. The subsonic values were measured in flight at the R.A.E.; the supersonic values were estimated by theoretical considerations and are certainly of the right order. Again it would be a bold man who thought he could join the two parts of the curve with any assurance.

We are thus driven to the inexorable conclusion that only by experiments of the kind I have suggested can we learn enough to make the design of aircraft for flight in or

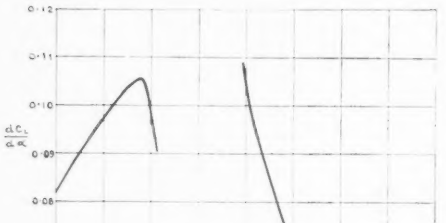


Fig. 13
Mach number
Slope of Lift Curve of Supersonic Aerofoil.

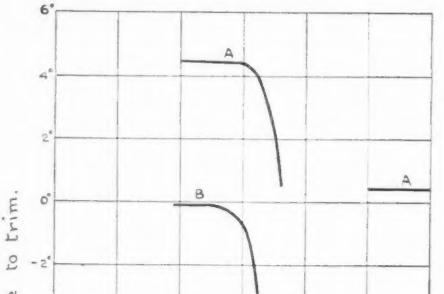


Fig. 14
Mach number
Elevator Angle to trim for two different Aeroplanes, A and B.

through the transonic region a safe procedure; we cannot guess the answer from what we already know, except possibly in the case of the drag coefficient. It is thus necessary to develop a new and very difficult experimental technique if we wish to put our knowledge on a firm basis. It may not prove very difficult to measure simple things like drag, but the detailed study of such things as control characteristics on a free projected model moving at about 700 miles per hour may well tax our ingenuity to the utmost.

There is also the still more difficult problem of flutter in the transonic region. Even in the range of high Mach number covered by the wind tunnel nothing has yet been done to study this important subject, because of the utter inadequacy of the number of high speed tunnels now available.

This matter of the transonic region is urgent. It may be some time before aircraft are developed which fly through the region and attain supersonic speed, but our present-day machines can get very nearly up to speed of sound in a dive. It is now quite a long time since a Spitfire attained a Mach number in the neighbourhood of 0.9, and

the development of jet propulsion, together with continued aerodynamic improvement of design, may be expected to increase this figure. With conventional designs of aircraft, however, the increase is slow, because of the extremely rapid rise of drag near the sonic speed.

But is this rapid rise of drag unavoidable? We are beginning to think that it is not, or at least that it can be put off till a still higher Mach number is reached, possibly a supersonic one. Very little is known basically about drag in the region well above the critical Mach number but still below unity, for theory has so far failed to provide solutions to flow problems where parts of the field are subsonic and other parts are supersonic.

We know from experiment that a shock wave first forms near the point of maximum suction on the wing, that the shock wave becomes " stronger " and moves back on the chord as the Mach number increases, and that at supersonic speeds it reaches the trailing edge and is accompanied by another shock wave springing from the leading edge. But we have not yet evolved a theory which will predict these changes, and give information on the strength of the shock wave and the resultant forces in any given condition.

We are therefore forced to rely on experimental evidence, and, as I have already pointed out, at present this is restricted severely by the limitations imposed by the wind tunnel. We know, however, that different wing sections behave in different ways in the high subsonic region, and in particular that a high value of the critical Mach number does not necessarily imply the best behaviour at still higher Mach numbers.

This is illustrated in Fig. 15, which shows the drag curves of three symmetrical aerofoils having their maximum thickness at 0.3, 0.4 and 0.5 chord respectively. The critical Mach numbers are indicated by crosses and it is seen that the order of these critical numbers is no guide to the order of the curves above a Mach number of 0.8. In fact, the aerofoil marked 0.5 has the highest critical and is nevertheless the worst of the three at the higher Mach numbers.

A few results for cambered aerofoils are available and these suggest that the symmetrical sections are the best at Mach numbers well above the critical, especially when the maximum thickness is set at about 0.4 chord. It thus appears that symmetrical sections are likely to be very good for high subsonic speeds, not only on account of drag, but also because they give less violent changes of pitching moment.

There is another way in which much more striking drag reduction seems to be possible, and this was first brought to the attention of British scientists by a study of German work done in the war years. I refer to the effect of a large sweep-back of the wings, a subject which is uppermost in many minds at the present time.

There is a theoretical argument which indicates the nature of this effect. Consider the potential flow round a two-dimensional wing moving in a direction perpendicular to its leading edge, that is, with zero sweep-back. Now superpose on this motion a velocity of the wing in the direction of its span. This will evidently have no effect on the

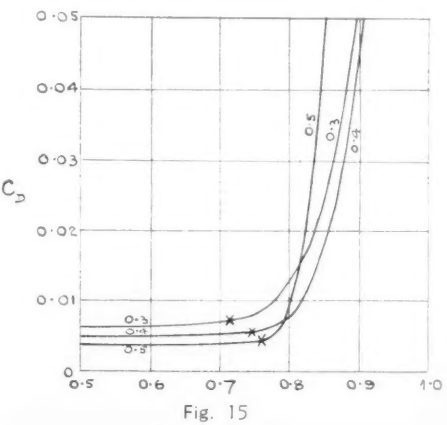


Fig. 15

Drag of three Aerofoils showing that the critical Mach number is no guide to super-critical behaviour.

pressure distribution, but the resultant velocity is now increased and is at an angle, as though we had given the wing a sweep-back.

It is argued from this that with a swept-back wing of infinite span, only the component of the velocity normal to the leading edge is effective in determining the forces on the wing. On this simple argument we should expect the forces at low speeds to decrease as the square of the cosine of the sweep-back angle.

When this theory came to our notice I looked up some old experiments on the pressure distribution over a yawed R.A.F.15 aerofoil of aspect ratio 6, made by Williams at the N.P.L. in 1928. Though the conditions are not two-dimensional, these tests show that the pressure at a given point at the mid-section of the wing does in fact fall with yaw roughly as the square of the cosine. (I instance this as an interesting example, and they are many, of a fundamental fact inherent in an old experiment, but which is not appreciated or explained until some new observation brings it forcibly to notice.)

When the speed of motion exceeds that corresponding to the critical Mach number, a more spectacular drag decrease is to be expected, for the theory suggests that we have reduced the effective *Mach number* of the section in the ratio of the cosine of the sweep-back angle. Thus if the critical Mach number of a thin section were 0.8 we might expect to be able to use it at a Mach number of unity without any compressibility drag rise if it were swept back through an angle of $\cos^{-1} 0.8$ or 37°.

This is such a surprising conclusion that a direct experimental verification of it would be very welcome. The theory is, of course, incomplete when applied to a real problem since it neglects viscosity, in the presence of which the spanwise component of velocity can obviously affect conditions in the boundary layer. We might expect, therefore, that drag at low speeds would not behave precisely as the theory indicates, but that shock wave effects, which depend rather on the pressure distribution than on the viscous forces, would very likely do so.

I can show you a little evidence from the rectangular high speed tunnel at the N.P.L., in which an aerofoil was tested for drag by the pitot-traverse method, first straight across the tunnel and then inclined at 45°. The curves, Fig. 16, show that something like half the predicted improvement was realised, as shown by the Mach number at which the drag rises rapidly. The failure to realise a greater gain may well be due to end effects, for the chord of the aerofoil was one quarter of the distance between the tunnel walls.

Accepting for the moment that the two-dimensional theory would be borne out by a really two-dimensional experiment, there remains the question of how far the indicated gain can be realised when the aspect ratio is finite, and particularly when it is fairly small, as is likely to be the case for aircraft with rather thin wings. This question can only be answered by experiment and again we are confronted by the difficulty that the wind tunnel fails us just as we approach the speeds in which we are mainly interested.

The Germans had made some experiments of this kind. Their results show again that only about half the theoretical gain is realised, and this is attributed to the departure from two-dimensional flow at the centre and tips. It can be easily seen, by considering the combination of the varying chordwise

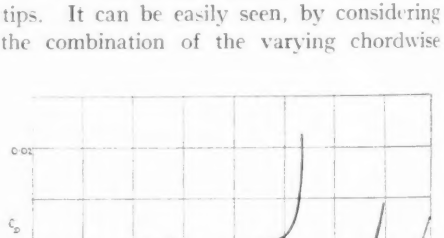


Fig. 16

Mach number

Two-dimensional test of a Swept-Back Wing in the N.P.L. Rectangular High-Speed Tunnel

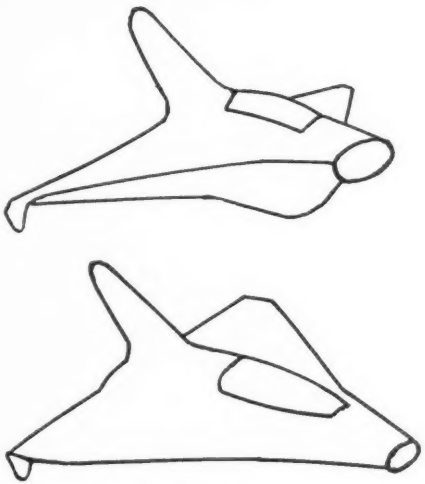


Fig. 17
A Lippisch Design for a Supersonic Aircraft

velocity component with the constant spanwise component that the flow near the centre section will be convergent, so that there is a tendency for high speeds and early shock stall in this region.

While arguments of the kind I have advanced suggest that very considerable increases of speed without drag coefficient increase may be obtained by using large sweep-back, the adoption of this device will involve the solution of other problems connected with sweep-back, of which perhaps the most serious is the tendency to earlier tip-stalling. This phenomenon is well known to designers of tailless aircraft and presents a major difficulty in obtaining adequate control and stability during take-off and landing. Obviously the difficulty will become greater as the aspect ratio is reduced, while the proportion of the theoretical gain in drag will, presumably, decrease. It would appear that there will be a best compromise between these two considerations which can only be arrived at by experiment.

The extent to which the Germans themselves have been led by arguments of this kind is illustrated well by Fig. 17, which shows a design for a supersonic aircraft by Lippisch. Structurally it should present no great difficulties; aerodynamically it is probably very good at high subsonic speeds and in supersonic flight, but one can well imagine that it would present very considerable difficulties in attaining good control at low speeds. A little ordinary wind tunnel work on a design of this kind would give a useful indication of the practicability of such a revolutionary lay-out.

In summarising this part of my lecture I can safely say that the transonic region is at present the greatest unknown in the quest for higher and higher speeds of flight, and that it presents great difficulties of investigation owing to the fact that ordinary laboratory methods fail and we are being forced to develop a new technique. Here, indeed, is an almost virgin field for the research worker of the immediate future. I do not imagine for one moment that man will be happy until he has conquered the " sonic barrier "; any experiments that we can perform to help him over the difficult threshold to supersonic flight will be of great value and may well save the lives of intrepid pioneers in this new and hazardous venture.

PROPULSION

I make no apology for a few words on the subject of " engines " in a lecture on aerodynamic developments, for the jet propulsion type of power plant involves aerodynamic problems at least as much as engineering ones. Moreover, its progeny, especially when they indulge in supersonic flight, may well become almost purely aerodynamic.

The ordinary jet engine is now so well known that it is almost unnecessary to describe its action. Suffice it to say that the intake air is compressed by a centrifugal or axial blower, fuel is burned in the high pressure air and the energy of the resulting expansion is partly used to actuate a turbine driving the compressor and partly to provide the jet reaction for propulsion.

The efficiency of the process depends almost entirely on aerodynamic considera-

tions. The compressor and turbine depend on aerodynamic reactions related to those of simple aerofoils, while the intake and ducting must be designed to minimise loss of energy by any break-away of flow in them; they must be "internally streamlined," so to speak. Moreover, the air and gas speeds are high, so that the Mach number of the internal flow may often approach unity. It follows that general theoretical and experimental work on air flow at high Mach numbers now has a very direct bearing on the design of the engine as well as the aeroplane.

Compared with the reciprocating engine, the jet engine is light and simple, and lends itself to good aerodynamic design in a way which is quite impossible in the piston engine with its awkwardly shaped ports, valves, and gas-ducts. This fact can offset to some extent the lower thermal efficiency of the gas turbine, which is of course due to the fact that the maximum temperature permissible in the blading is a lot lower than that which can be allowed in the cylinder of a piston engine. Even at moderate speeds the gas turbine may provide the best means of propulsion in some cases, for its lightness offsets the greater specific fuel consumption if the endurance is not too long, and the advantage of using a heavier and safer fuel than petrol is by no means negligible.

When, however, we come to really high speeds, there seems no alternative, since the gas turbine alone can provide the necessary thrust without becoming of such unwieldy size that it cannot be accommodated in the available space. Moreover, with conventional power plant, it seems highly unlikely that a good airscrew efficiency can be maintained when the Mach number exceeds about 0.8.

When we come to supersonic flight speeds a curious position arises. The compressor of the jet engine becomes less and less a necessity as the speed increases because the compression of the air at the intake *due to the forward motion*, the so-called ram effect, becomes increasingly able to provide the pressure ratio required for the subsequent processes of combustion and ejection. If, for instance, we assume that there is a plane normal shock wave across the entry duct, the pressure ratio is 3.65 at a Mach number of 1.5 and 7.85 at a Mach number of 2.0.

It is quite likely that these pressure ratios can be improved by designing the intake so that the flow just inside it is still supersonic, the pressure recovery taking place through one or more inclined shocks followed by a weak normal shock. There is a field for research here, and something has already been done to explore it, but I fear I have not time to go into details.

The "engine" to which these ideas lead is, in a sense, no engine at all. It is merely a duct in which aerodynamic and thermal changes occur, and it has been described as an aero-thermodynamic-duct, a somewhat lengthy word that some have contracted to "Athodyd" for convenience. The principle is precisely the same as that of the normal gas turbine except that the initial compression is now entirely due to ram effect, and so there is no rotating part at all. Since the compression increases with speed, so also does the thermal efficiency. Moreover, there is not likely to be so much trouble with high temperatures as there is in the slender blading of a turbine.

The one difficulty lies in the fact that the action *depends* on the forward speed; the "static" thrust is zero and the "take-off" thrust negligibly small. The use of the athodyd for supersonic flight will thus involve some other source of power, possibly rockets, to accelerate the aircraft to a speed sufficient to allow the athodyd to begin to work with reasonable efficiency. An alternative may be to carry normal gas turbines plus athodyds.

As far as I am aware no complete test of this new propulsive device has yet been made, save for a very tentative experiment on an athodyd about one inch in diameter in the twelve-inch supersonic tunnel of the

N.P.L. The fuel used was hydrogen, for ease of introduction, and the drag measurements made showed definitely that a considerable thrust was developed. Unfortunately the " model " was not sufficiently robust and showed signs of distress under the high temperatures before the tests could be completed and before the hydrogen consumption had been determined.

The object of the test was to compare a measured thrust with that calculated. There is no reason to doubt calculated values provided that the intake conditions are known, so that the right shock wave formation at the intake can be used in computing the pressure in the combustion chamber. The difficulty is to be sure of these intake conditions, which are known to depend on the " effective blockage " in the duct due to the processes of compression, combustion and subsequent expansion to the outlet jet. Here again, is a most interesting and fruitful field of research for the future.

Before concluding this brief reference to new means of propulsion I must mention the bi-fuel rocket, of the kind used by Germany in the V-2 weapon, and in a short duration, high performance fighter. It has the inherent disadvantage of high fuel weight, since the oxygen as well as the combustible must be carried, but its interest lies in the fact that it may well provide an easy way to make supersonic flights in experimental aircraft for the purpose of beginning to study, in the air, the new problems involved. This is because the high temperature that is possible in the short combustion chamber and exit nozzle allows the production of a far higher specific thrust than can be obtained in the same space from a gas turbine, while avoiding the difficulty of take-off associated with the athodyd. It provides, in short, a very high thrust which is almost independent of speed or altitude.

I shall be accused of not being up-to-date if I do not at least mention atomic energy! I am no expert in this field and cannot guess what the possibilities are, but from what is said it does not seem likely that the use of atomic energy in small packets and in close proximity to persons will become possible soon enough to affect the desirability of developing to the full such innovations as I have outlined in this lecture.

Needless to say, the possibility of a propulsive agent which involves an almost negligible weight would revolutionise all our ideas about high speed aircraft. In fact, it would leave only one barrier to the attainment of almost any speed we wished: the barrier of temperature rise. This limitation may soon prove quite serious, even with methods of propulsion that we can now foresee.

As is well known, the surface of a body in motion is raised in temperature by very nearly the thermal equivalent of the kinetic energy, that is, by an amount $V^2/2C_p$ or its equivalent $M^2T/5$ for air, where M is the Mach number and T the absolute air temperature. Thus for a Mach number of 1.4 the rise is 85° C. in the stratosphere, and for $M = \sqrt{5}$ the absolute temperature of the air is nearly doubled.

So, if we travel for long at speeds well above that of sound the problem will be not to keep the pilot and passengers warm, but to keep them cool, even at great altitudes. No doubt refrigerating engineers can cope with the problem for some time to come, but it does seem that if almost unlimited power ever becomes available for propulsion the limit to man's achievement in speed may finally be set by temperature. Not even the most ardent pioneer would like to become quite as hot as a meteorite!

CONCLUSION

In this lecture I have deliberately not gone into any great detail; I have tried, and I hope I have succeeded in some small degree, to indicate the nature of the new ideas that have arisen recently in aerodynamic research, and to show what bearing they have on the

future of aviation. Progress has indeed been rapid in this youngest branch of Engineering. When we realise that it was only forty-three years ago that the Wright Brothers made the first flight under power, and that now we have flown horizontally at 606 miles per hour and speak calmly of attacking supersonic flight seriously, we may well be appalled at the rapidity with which man has progressed in his conquest of the air.

In the past there have been periods in which the greatest advances came from improved engines, and others marked by great improvements in cleaner aerodynamic design. It looks very much as though the next period will be characterised by both, for we see glimmerings of the possibilities of drags far lower than anyone could have hoped for a few years ago, while on the engine side the recent marked successes of jet propulsion can only be the first-fruits of the new forms of power plant.

I do not believe there was ever a period in aeronautical history so bright with the possibility of future progress. I can only hope that we shall be wise enough not to allow the inevitable retrenchment after a long and costly war to hamper too seriously our search into the unknown. To my mind the one thing on which we should not cut down expenditure is research, for it is only by research that we can be ready to meet the demands of the future, whether they be as we all hope, the furtherance of the brotherhood of man, or whether they be as some fear, the necessity again to defend ourselves against a foe.

Indeed I would be so bold as to suggest that we ought greatly to increase our research facilities for two very good reasons. One is that the war has produced so many urgent problems that we have not had time for the leisurely but very hard thinking, which constitutes the research method. The result is a surfeit of *ideas* arising in all manner of ways, but not followed up or thought out in detail. We are therefore behind-hand with the *implication* of these ideas, a process which will involve a lot of work by a lot of men.

The second reason is even more important. The researches arising from the ideas I have sketched in this lecture need, for their proper study, equipment of a kind which we do not possess in this country; equipment which, in some cases, is complex and costly. If we do not provide such apparatus, and that quickly, we shall lose a great opportunity for British aeronautical science.

Lastly, one other thing that I hope most fervently is that we may be able in the future to advance hand-in-hand with our great wartime ally and friend, the United States of America. Surely the continuance of the close co-operation which was so effectively established during the war years into the years of peace, would be the greatest tribute we could pay to those two great men who did so much to inaugurate the aerial age, and in whose honour we hold this Wilbur Wright lecture every year.

Dr. H. ROXBEE COX, Vice-President of the Society, Fellow :—

The Wilbur Wright Memorial Lectures formed a remarkable and distinguished series which were of great historical interest and which had had a notable influence on aeronautics. To the majority of them Mr. Relf's lecture would have been a series of revelations recognisable as of the greatest significance. Even the minority who had some foreknowledge of these matters must have been impressed afresh to-night by the strength of the aerodynamic hand they had to play—a hand to be played boldly and to be backed with all the money they could spare.

They were, perhaps, told a little too often that they were at the dawn of a new era. They had had dawns ushered in by atomic energy, UNO, jet propulsion and a variety of other things. But even though the metaphor was a bit overworked, it was a good one, and there was not much doubt that they were at the dawn of a new era in aerodynamics. A Mach Number era.

It was a particular pleasure to him to be proposing a vote of thanks to the lecturer because he was a very old aeronautical friend of his. They first met in 1923 when, as a student, he worked for a time at the National Physical Laboratory. It was not long before he became aware of Mr. Relf's extraordinary versatility.

At that time he was solving a problem in the theory of structures, was conducting wind tunnel experiments, and had just completed the ingenious tank device which applied the analogy between an electrical field and flow in a perfect fluid to the solution of hydrodynamical problems. He soon learned, too, that he was a considerable musician. But it was as an aerodynamicist that he was supreme

one of the greatest they had. Be it through study, through experience, or through intuition, or through all three, his knowledge of how even the thinnest air will behave or misbehave in a given set of circumstances was uncanny.

There was no doubt that by inviting him to give the Wilbur Wright Lecture this evening the Society had honoured one of their most eminent men, and he had honoured them with an exposition which would have a tremendous influence on aeronautical thought, not only in this country and in the country of the man to whose memory the lecture is dedicated, but in the rest of the World. Consequently it was with the utmost sincerity that he proposed that they vote their thanks to Mr. Relf.

Sir OLIVER SIMMONDS, Vice-President, Fellow :—

The proposer of the vote of thanks, which he had great pleasure in seconding, had himself set a new high standard in the last Wright Brothers Lecture, the corresponding lecture in America to the one they had just heard by Mr. Relf.

These lectures were of real importance because both the American and British Governments were willing to give great facilities to the lecturers. They owed a debt to Sir Ben Lockspeiser for the help he had given in the present lecture.

The Wilbur Wright Lecture had been delivered now on 34 occasions without a break, in spite of two major wars, and he was exceedingly glad to welcome there to-night Mr. Griffith Brewer who had done so much to ensure that continuity and to whom was due the very founding of the Lecture.

Mr. Relf had given them a great inspiration for the future. He had great pleasure in seconding the vote of thanks.

The vote of thanks was carried with acclamation.

Following the Lecture the Annual Council Dinner was held at which the following were present :—

Mr. E. J. N. Archbold, B.Sc., Grad.R.Ae.S., Member of Council.

Professor L. Bairstow, C.B.E., F.R.S., F.R.Ae.S.; Major-Gen. Clayton L. Bissel, U.S. Embassy; Mr. J. W. Booth, J.P., Chairman, British South American Airways; Air Marshal Sir Norman Bottomley, K.C.B., C.I.E., D.S.O., O.C. Bomber Command; Lord Brabazon of Tara, M.C., F.R.Ae.S., Member of Council; Mr. Griffith Brewer, Hon. F.R.Ae.S., Past President; Sir John S. Buchanan, C.B.E., A.M.I.Mech.E., F.R.Ae.S., Member of Council; Major G. P. Bulman, C.B.E., B.Sc., F.R.Ae.S., Member of Council.

Mr. S. Camm, C.B.E., F.R.Ae.S., Member of Council; Air Marshal Sir Arthur Coningham, K.C.B., D.S.O., M.C., A.F.C., D.F.C., O.C. Flying Training Command; Air Marshal Sir Alex Coryton, C.B.D.; Dr. H. Roxbee Cox, Ph.D., D.I.C., B.Sc., F.R.Ae.S., Vice-President.

Mr. G. P. Douglas, O.B.E., M.C., D.Sc., F.R.Ae.S., Member of Council; Dr. T. Dunsheath, O.B.E., President, Inst.E.E.

Mr. A. G. Elliott, C.B.E., M.I.Aut.E., M.S.A.E., F.R.Ae.S., Member of Council.

Mr. W. S. Farren, C.B.E., F.R.S., F.R.Ae.S., Member of Council; Sir A. H. Roy Fedden, M.B.E., D.Sc., M.I.Mech.E., M.I.A.E., M.S.A.E., F.R.Ae.S., Past President; Mr. Oliver Franks, Permanent Secretary, Ministry of Supply.

Professor S. Goldstein, F.R.Ae.S., Chairman, Aeronautical Research Council; Mr. A. Gouge, B.Sc., F.R.Ae.S., Member of Council; Colonel John Griffith, U.S. Military Air Attaché.

Sir Frederick Handley Page, C.B.E., F.R.Ae.S., President; Sir Harold Hartley, K.C.V.O., M.C., F.R.S., British European Airways Division of B.O.A.C.

Captain J. J. Ide, Office of Naval Air Attaché, U.S. Embassy.

Mr. E. T. Jones, O.B.E., M.Eng., F.R.Ae.S., Member of Council.

The Rt. Hon. The Viscount Knollys, Chairman, British Overseas Airways Corporation.

Sir Ben Lockspeiser, M.A., F.C.S., F.R.Ae.S., Member of Council; Air Chief Marshal Sir Edgar Ludlow Hewitt, G.C.B., G.B.E., C.M.G., D.S.O., M.C.

Major R. H. Mayo, O.B.E., M.A., A.M.Inst.C.E., F.R.Ae.S., Member of Council.

Mr. W. G. A. Perring, F.R.Ae.S., Member of Council; Captain J. Laurence Pritchard, Hon. M.I.Ae.S., Hon. F.R.Ae.S., Secretary of the Society.

Mr. E. F. Relf, C.B.E., F.R.S., F.R.Ae.S., Principal, College of Aeronautics; Air Marshal Sir James Robb, K.B.E., C.B., D.S.O., O.C. Fighter Command; Mr. N. E. Rowe, C.B.E., B.Sc., D.I.C., F.R.Ae.S., Member of Council.

Mr. Livingstone Satterthwaite, Civil Air Attaché, U.S. Embassy; Mr. S. Scott Hall, F.R.Ae.S., Principal Director of Technical Development, Ministry of Supply; Sir Henry Self, K.C.M.G., K.B.E., C.B., Permanent Secretary, Ministry of Civil Aviation; Lord Sempill, A.F.C., F.R.Ae.S., Past President; Sir Oliver Simmonds, M.A., F.R.Ae.S., Vice-President; Air Marshal Sir Leonard H. Slatter, K.B.E., C.B., D.S.O., D.F.C., O.C. Coastal Command; Rear Admiral M. S. Slattery, C.B., F.R.Ae.S., Admiralty; Air Marshal Sir Ralph Sorley, K.C.B., O.B.E., D.S.C., D.F.C., O.C. Technical Training Command; Professor R. V. Southwell, F.R.S., F.R.Ae.S., Rector, Imperial College; Air Commodore Whitney Straight, C.B.E., M.C., D.F.C., Chairman, Royal Aero Club.

Air Chief Marshal Lord Tedder, Chief of the Air Staff; Mr. Ivor Thomas, M.P., Parliamentary Secretary, Ministry of Civil Aviation; Rear Admiral Sir Thomas Troubridge, C.B., D.S.O., Fifth Sea Lord.

Captain C. F. Uwins, A.F.C., O.B.E., F.R.Ae.S., Honorary Treasurer.

Mr. B. N. Wallis, C.B.E., F.R.S., B.Sc., R.D.I., M.Inst.C.E., F.R.Ae.S., Member of Council; Mr. H. E. Wimperis, C.B., C.B.E., F.R.Ae.S., Past President; Mr. L. A. Wingfield, M.C., D.F.C., A.R.Ae.S., Solicitor; The Rt. Hon. Lord Winster, Minister of Civil Aviation; Mr. Arthur Woodburn, M.P., Parliamentary Secretary, Ministry of Supply.

THE ROYAL AERONAUTICAL SOCIETY

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METHOD OF ACCIDENT INVESTIGATION AND PREVENTION ADOPTED BY AIR TRANSPORT AUXILIARY

by

P. A. WILLS, C.B.E

Mr. Wills was a well-known light aeroplane and glider pilot before the war and was one of the original band of pilots who joined Air Transport Auxiliary in September 1939. *He was second-in-command to Commodore G. d'Erlanger, Officer Commanding Air Transport Auxiliary, and was Chairman of the Accidents Committee. Mr. Wills is now Technical Director of the British European Airways Division of the British Overseas Airways Corporation.*

INTRODUCTION

A LARGE number of individuals took part in the development and application of the methods of accident investigation and prevention outlined in the following paper. Commodore G. d'Erlanger, C.B.E., O.C. Air Transport Auxiliary, took a major part in the general evolution of the procedure; Air Vice-Marshal Sir Lawrence A. Pattinson, C.B., D.S.O., M.C., D.F.C., with his great knowledge of R.A.F. procedure, was responsible for the production of the A.T.A. manual " Instructions for Reporting Flying Accidents, Forced Landings, Aircraft Defects and Casualties "; and starting from scratch, a very competent Secretariat, consisting of Flt/Capt. G. Merton, F/O D. G. Brinjes and F/O J. W. Gibbs, were responsible for the great amount of work involved in working the machine and in the eventual production of the data and information summarised herein. The Chief Medical Officer, A.T.A., Cmdr. A. Buchanan Barbour, is in general responsible for those paragraphs of this paper covering the field of aviation medicine.

Thanks are also due to Air Commodore Vernon Brown, O.B.E., Chief Inspector of Accidents, Air Ministry, for unfailing advice and assistance which was available whenever required.

PART I.

When considering accident investigation problems it is necessary to have a clearly defined picture of the purpose of the investigation. Before considering the data offered in the following treatise and the conclusions which have been drawn from this data, it is as well to have a clear picture of the machinery of accident investigation built up in A.T.A. by experience over the period of its existence.

1. PURPOSE OF ACCIDENT INVESTIGATION

The major purpose of accident investigation is the prevention of further accidents or a reduction in the accident rate.

After an accident has occurred, little that can be done can minimise the direct loss caused, but nearly always steps can be taken to minimise the risk of a similar accident happening again. This prime purpose has sometimes been obscured by others, such as:

(*i*) A desire to assess blame, or

(*ii*) Financial considerations.

2. Such extraneous considerations have often obscured the first law of accident investigation, *that the amount of damage done in an accident has no bearing on the importance of the accident from the " prevention of further accidents " point of view.*

Frequently, a valuable lesson can be drawn from an " accident " in which no damage is done; and conversely, no lesson at all from a fatal accident involving the loss of an aircraft and many lives. Hence the undesirability of classifying accidents as " major " and " minor," or of ruling that no accident need be investigated if the damage done can be repaired in, say, 48 hours.

Take an imaginary example: the failure in the air of a badly designed fuel pump causes complete engine failure. One pilot with exceptional skill lands without damage. Another, over hopeless country, crashes and all on board are killed. The seriousness of the defect, and the urgency of redesigning the component, is exactly the same in each case, yet under a "major and minor" ruling, or " 48-hour " ruling, the first accident may go uninvestigated, but the second gets full investigation. If the first is investigated in time, the second may never happen. From the point of view of the accident investigator both accidents have exactly the same importance, *i.e.* their potential value for the prevention of future accidents are the same. In one respect the less serious accident may frequently produce more valuable results in that those on board, being still alive, are available to give evidence of what actually happened.

As another instance, a pilot through neglect mismanages his petrol cocks and loses his engine. He may then get down without damage or he may crash and destroy his aircraft. In either case he is equally blameworthy.

3. It will be seen from the above that in this context the word " accident " and the term " forced landing," together classed as " reportable occurrences," must have very special and clearly defined meanings. In A.T.A. they were defined as follows:

Flying Accidents. The term " flying accident " covered all aircraft accidents involving injury to persons or damage to aircraft, except those attributable, or assumed to be attributable, to enemy action.

The term, therefore, included not only accidents occurring in flight but also those occurring:

(*i*) in starting up engines
(*ii*) in taking off
(*iii*) in landing or alighting on water
(*iv*) in taxying
(*v*) in hoisting an aircraft out of, or into, a ship and securing it on board
(*vi*) when the aircraft was being pushed or towed or manhandled
(*vii*) when the aircraft was stationary on the ground, on the water or in a hangar, including when it was picketed or moored.

Forced Landings. The term " forced landing " covered any landings, whether at the airfield of departure, or destination or elsewhere, which were not premeditated before the flight began, except those attributable, or assumed to be attributable, to enemy action.

The failure during flight of one or more engines on multi-engined aircraft was deemed to constitute a forced landing.

A successful forced landing meant a forced landing in which there was neither injury to any person, nor damage to aircraft (as defined below).

Damage to Aircraft. An aircraft was considered as " damaged " unless the damage sustained was so trivial as not to make it unfit for flying.

Every incident falling under the definitions of " Flying Accident " and " Forced Landing " given above was investigated, except the following:

Successful forced landings made for reasons not connected with the fitness of the aircraft to continue in flight, and which did not involve engine failure, and as a result of which no salvage facilities were required. Under this heading were included such landings as were made on account of weather, or refuelling, or the pilot losing his way or mislaying his maps,

or for the correction of minor defects covered by Snag Reports, and so on.

4. Pilots do not want to have accidents, and if the prime purpose of the accident investigator is to prevent further accidents it should not be difficult to persuade pilots to give him every assistance in his work. *It is of cardinal importance to get the pilot's co-operation.*

The pilot who has had an accident may or may not have been an ass, but he may very probably have learned a fact of the utmost importance to others. In this sense he is, for the time being, an important person. If he is treated as a dolt or a criminal by a Committee, which, alas, may include persons who have little practical, or at any rate, little recent experience of the difficulties and "catches" of flying modern aircraft, he may, in resentment or self-protection, try to cover up what really happened.

The more pilots and other personnel concerned can be persuaded that the fundamental aim of the investigation is not punitive but preventative, the more their full co-operation can be obtained and the quicker will the accident rate come down.

In a small proportion of accidents, disciplinary action must be taken, but this is a by-product of the investigation and should never be taken or recommended directly by the investigating body. Most pilots, in the true sense of the word, are craftsmen, and their own feelings on breaking their most cherished instrument are frequently the worst part of the punishment.

Suggested methods of obtaining this much-needed co-operation are:—

(*i*) have on the Committee at each sitting a senior operational pilot, drawn from a different unit for each occasion. In this way the news will rapidly go round the organisation that the Committee does its work in a fair and efficient manner;

(*ii*) when an accident has been caused by a technical defect, faulty maintenance, or the like, the eventual technical report and resultant curative action may not come through for some time. When it does, a copy should usually be sent to the pilot's C.O. and shown by him to the pilot or person concerned. This will demonstrate that the Committee does not confine itself to assessing responsibility, but does follow up each and every accident to its conclusion;

(*iii*) take all possible steps to keep the purpose of accident investigation in the minds of all concerned. (See Appendix I, para 2);

(*iv*) the carrying out and conclusion of all investigations as quickly as possible after the event is important. Serious delays keep those concerned in a suspense which leads to irritation adversely affecting the general attitude towards the Accidents Committee. In A.T.A. the average time elapsing between an accident and a finding was around 14 days, although in a few cases technical investigations stretched out this period considerably.

5. Accident investigation is a highly specialised business. Accordingly, the investigation of an accident should not be delegated to a comparatively small unit which, over a period, will experience only a small number of accidents. Instead, the clearest possible instructions should be issued to all units as to the types of reports and evidence which must be obtained after accidents, and these should then be forwarded to a central body, whose business it is to consider accidents in comparatively large numbers. In this way recurrent pilots' mistakes or mechanical defects and so on will most quickly be identified and remedial measures expedited; and only in this way can the same yardstick be applied to each accident and justice done.

This means that Courts of Inquiry on the spot should be reduced to the minimum. In accordance with the main law of accident investigation outlined above, Courts of

Inquiry should not be held simply because an accident has resulted in loss of life or serious damage.

In accidents of considerable complexity a trained area accident investigator should be available immediately to assist on the spot in compiling the necessary evidence for submission to the Accidents Committee. Formal Courts of Inquiry then become necessary only in cases where, *e.g.* an accident involves persons of more than one Service, or aircraft of different countries.

COMPOSITION OF ACCIDENTS COMMITTEE

The Accidents Committee should be composed of one expert for every department commonly concerned in aircraft accidents. These should include:

Chairman. Preferably a pilot, to give him standing with other pilots.
Secretary.
Operational Pilot. A senior operational pilot, from a different unit each week.
Expert Pilot. A full-time member to advise the Committee on pilotage problems.
Maintenance Engineer and
Development Engineer. Both must have thorough knowledge of all types of aircraft operated in the Committee's group.
Flying Control Officer. This officer should combine a knowledge of flying control and telecommunications.
Medical Officer. Expert in aviation medicine and psychology.
Senior Flying Instructor.
Radio Expert. To cover matters concerning radio and radar.
Meteorological Officer.

All concerned should be instructed that if, on receipt of the findings, they consider they have been unjustly treated they *must* appeal, submitting in writing the grounds upon which they found their views. On appeal they should be additionally called, if possible, to give evidence and explain the grounds of their objection at the re-hearing.

There should be a well-understood distinction between accidents caused by errors of judgment or bad airmanship and those caused by negligence or the breaking of an order. In A.T.A. "pilot responsible" defined the first, "pilot to blame" the second. Curative action on the first type might be a medical check or a refresher course. The second might involve disciplinary action.

A pilot was held "responsible" for *e.g.* a heavy landing resulting in damage, and would probably get a medical check and flight check. He was held "to blame" for an accident, *e.g.* caused by deliberate low flying, for which he might very well lose his job.

Just as an aircraft was categorised after an accident according to the degree of damage sustained, so in A.T.A. a pilot was also classified before being permitted to fly again. This was done on the R.A.F. accident form 765(c), the following code being used:

Pilot cat. A—pilot returned to duty
,, ,, B—pilot referred to medical authority for examination before being returned to duty
,, ,, C—pilot referred to Director of Training for flight check, etc.

Cat. B was used whenever a pilot might have suffered shock. A particular case was when an expert pilot had a stupid accident—medical or psychological trouble was immediately suspected. (See Appendix I, para 3.)

6. The final A.T.A. form in which the finding was promulgated had headings as follows:

Subject: a brief description of the event
Cause:
Responsibility—the finding here would be either:
"Not responsible and commended"
"Not responsible"
"Responsible"

"To blame"
"Insufficient evidence to assess responsibility"

Recommendation:—this was the most important heading, against which was entered any recommendations made with the aim of preventing a recurrence of this particular accident.

Approximately 79 per cent. of accidents resulted in some recommendations for curative action, and as an example, during 1944 the following numbers of accidents were referred to the bodies stated:

H.Q. 41 Group R.A.F.—technical and maintenance	121
H.Q. 41 Group R.A.F.—airfield control	28
H.Q. 41 Group R.A.F.—other matters	10
M.A.P. Flying Control—airfield control	46
A.I.D. Inspector i/c—technical and maintenance at factories	85
Flag Officer Naval Air Service, and/or Commodore, N.A.S. (North)	18
Chief Engineer—technical and maintenance	45
Chief Engineer—other matters	19
Chief Technical Officer	13
Director of Training—flying training	38
Chief Medical Officer	9
Chief Operations Officer—discipline	31
Others	23

The small proportionate number of cases reported for aircrew discipline is underlined, not as an example of unusual worthiness of A.T.A. aircrew, but as showing that the scope of remedial action covers a much wider field than that of discipline.

Two exemplary findings are given as Appendix II.

7. It is important to issue regular summaries, in a concise and readable form, to all concerned. In A.T.A. such summaries were issued both monthly and quarterly, thus keeping all air and ground crews advised of accident trends, etc.

8. To recapitulate the salient points:

(*i*) The primary purpose of accident investigation is the reduction of the accident rate.

(*ii*) The amount of damage done in an accident has no bearing on the importance of that accident from the point of view of (*i*) above.

(*iii*) Clear definitions of such terms as "accident," "forced landing," "damage," etc., are essential.

(*iv*) Accident investigation should be conducted in such a way as to ensure the maximum of co-operation from pilots or other personnel concerned.

(*v*) Accidents should be investigated by an expert Committee situated at a level where a reasonably large number of accidents can be focused.

(*vi*) There should be regular promulgation to all concerned of accident summaries in a concise form, so that all parties may be kept interested and informed.

PART II.

INTRODUCTION

Before going on to discuss rates of accidents, a word of warning is desirable. No useful comparison can be made against rates of accidents between one organisation and another when the definition of the word varies as widely between different organisations as it does at the present time.

In A.T.A. the average duration of a ferry flight was approximately one hour. Therefore it might appear that any of the percentage rates quoted hereafter based on "journeys" could be expressed as a rate based on 10,000 hours flying, by simply moving the decimal point two places to the right. An attempt to do this produces some curious results. Thus the Class I total accident rate comes out at approximately 100 per 10,000 hours, and even the "not responsible" Class I accident rate is approximately 50. Sixty per cent. of these being technical failures, the accident rate due to technical causes only (on aircraft which were largely brand-new) shows the figure of 30. On the other hand, the Class V total accident rate is 46 and the Class V "A.T.A. Respon-

sible " rate as low as 10. The only true comparison, therefore, that could be made is of the *gradients* of the various graphs, indicating the speed with which the accident rates were brought down.

On all the following graphs, " A.T.A. Not Responsible " accidents include accidents for which A.T.A. were not responsible plus accidents on which the finding was " Insufficient Evidence." The latter findings were a negligible proportion of the whole, except in the case of fatal accidents, as is mentioned in the paragraphs of this paper devoted to this subject.

1. A.T.A. existed for a total period of just over six years, and delivered about 325,000 aircraft during that time.

Reliable figures of deliveries and accidents cover only the last four years and during this period 259,413 aircraft were delivered, occasioning 1,969 accidents and reportable occurrences. This gives an overall accident rate for ferry aircraft of .78 per cent. with A.T.A. responsible for .31 per cent and not responsible .47 per cent.

2. In what follows, accident rates have sometimes been expressed as a percentage of aircraft delivered and in others as a percentage per 100 " journeys." A few preliminary remarks on the methods of expressing accident rates may therefore be useful.

(*i*) *Deliveries.*

Since A.T.A.'s function was to deliver aircraft, a measure of A.T.A.'s overall efficiency was clearly the number of reportable occurrences expressed as a percentage of aircraft delivered. From some points of view, however, this figure is not particularly useful. In the course of a delivery an aircraft might have to make two or more separate flights, and the likelihood of an accident clearly depends on the number of flights made over any given period since, generally speaking, no more than one accident can be experienced in one flight.

(*ii*) *Journeys.*

If a delivery covered a long distance, it was frequently the practice in A.T.A., for operational reasons, to split the delivery into two or more stages, the aircraft being transited at an intermediate Ferry Pool. Such stages have been termed " journeys," and A.T.A. records provide quantitive details of the numbers of such " journeys."

(*iii*) *Flights.*

Particularly in the winter, a pilot might have to make intermediate landings due, for example, to bad weather during a "journey" as defined in the above. Such intermediate forced landings, not being made in accordance with written instructions, are not recorded, and therefore it has not been possible to provide any accident statistics based on individual flights. Such landings were such a small proportion of the whole that it is not considered that they produced any significant inaccuracies in the statistical results presented.

(*iv*) *Accidents per* 10,000 *Flying Hours.*

Accident statistics are frequently presented on the basis of so many accidents per 10,000 flying hours. As it is unusual for more than one accident to occur during a single flight, comparison of accident rates between one type of flying where flights average, say, less than one hour, and another where flights average perhaps as much as twelve hours, appears unsatisfactory.

3. That the methods of accident investigation outlined in Part I are on the right lines is considered proven by the results obtained, for the constant and rigid application of these resulted in the overall rate showing a constant decline throughout the years. For the first three years under review, the rate for each month was lower every year than the rate on the same month for the year before. Even in the fourth year the overall twelve-monthly rate was lower than that in all the previous three years. Rates are plotted graphically in Figs. 1 and 2, where accidents are expressed as a percentage of deliveries. As might have been expected, the winter accident rate was invari-

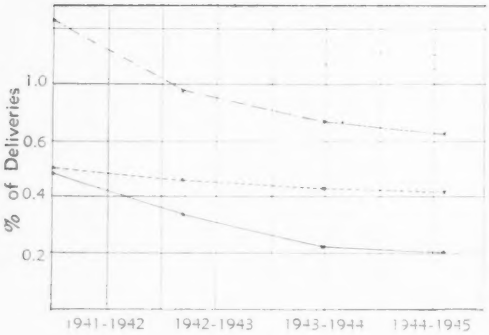

Fig. 1
Delivery Accident Rates
Yearly (Oct. 1st-Sept. 30th)
A.T.A. Responsible ——————
A.T.A. Not Responsible - - - - - -
TOTAL — — — —

ably higher than the summer rate, and this was caused largely by the increase in taxying accidents.

Records in the very early days of A.T.A. are somewhat inadequate, but insofar as memory serves the first band of approximately 40 highly-experienced amateur pilots produced surprisingly low accident rates. The need for rapid expansion of these numbers became imperative in the early months of 1940, and for some months the type of pilot taken in those days could not be subject to particularly careful selection. In particular, a large number of highly-experienced foreign pilots were brought into the organisation and put on ferrying with practically no conversion course. The fundamental differences of flying in America and other countries and in Great Britain, so unique in its weather conditions and density of population, were not appreciated, and these pilots in particular bumped up the accident rate until remedial steps were taken.

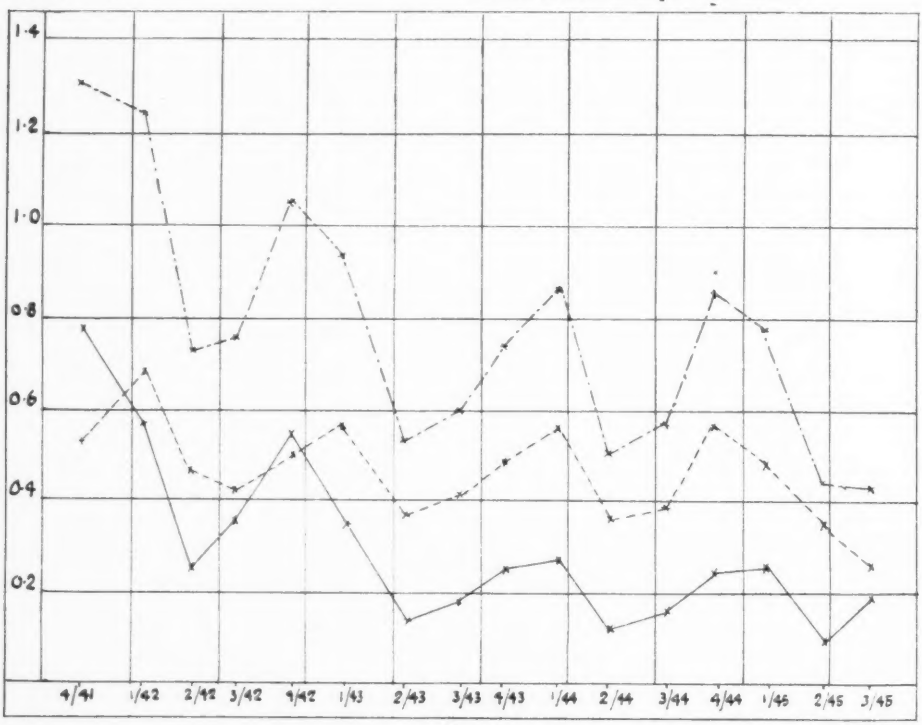

Fig. 2
Delivery Accident Rates, Quarterly: A.T.A. Responsible ——————
A.T.A. Not Responsible - - - - - -
TOTAL — — — —

4. ACCIDENT RATES BY CLASSES (Appendix III)

In A.T.A. pilots were progressed in accordance with classes of aircraft. Briefly, all aircraft were divided into six classes, as follows:

Class I	Single-engined light aircraft : Tiger Moths, Magisters, etc.
Class II	Single-engined Service types : Spitfires, Barracudas, etc.
Class III	Light twin-engined aircraft : Ansons, Oxfords, etc.
Class IV	Heavy twin-engined aircraft : Wellingtons, Hudsons, Meteors, etc.
Class V	Multi-engined landplanes.
Class VI	Flying-boats.

On entering A.T.A., a pilot was trained to Class I standard and then did a reasonable amount of actual ferrying in this class. In due course he returned to the School for conversion to Class II, then back for a period of actual ferrying on Classes I and II, and so on.

Thus, these classes had a changing population.

Class I (Figs. 3 and 4). Class I aircraft were ferried largely by pilots under training. Probably for this reason, the Class I accident rate, "A.T.A. responsible," is the highest of any of the classes. By far the largest item in this figure is the number of taxying accidents which account for one-third to one-half of the total. Bearing in mind the relative

Fig. 3
Class I Aircraft Accident Rate (Quarterly)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -

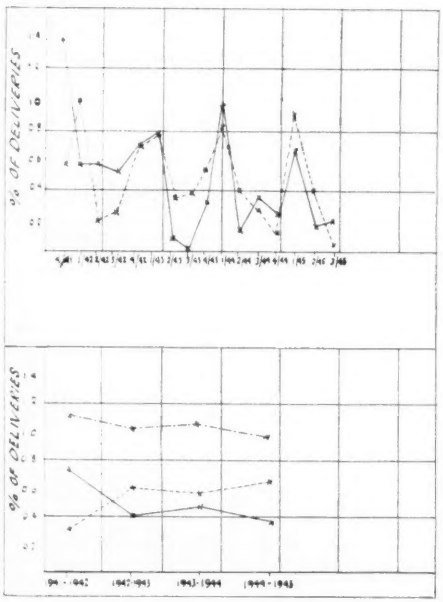

Fig. 4
Class I Aircraft Accident Rate
Yearly (Oct. 1st-Sept. 30th)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -
TOTAL - — - —

Fig. 5
Class II Aircraft Accident Rate (Quarterly)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -

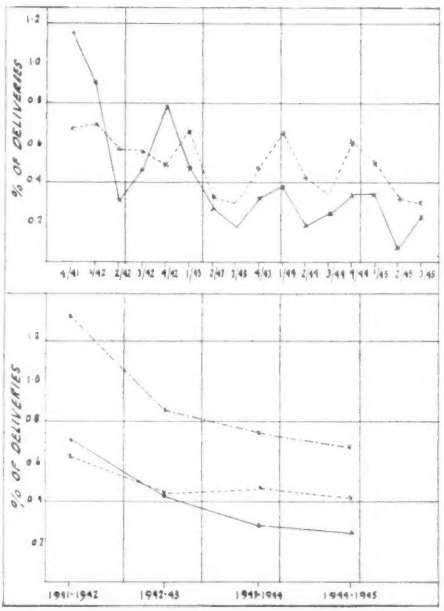

Fig. 6
Class II Aircraft Accident Rate
Yearly (Oct 1st-Sept. 30th)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -
TOTAL - — - —

simplicity of these aircraft, it is most surprising to find the " not responsible " rate higher than on the more advanced classes. More than half these accidents were due to engine defects.

Class II (Figs. 5 and 6). A fairly large proportion of Class II aircraft was also ferried by pilots under training. Since these aircraft are from many points of view the most difficult to handle, it is gratifying that the overall rate " A.T.A. responsible " is lower than for Class I aircraft, although higher than for twin- and multi-engined types.

The rate shows a constant downward trend, the greatest reduction being after the first recorded year when the bad weather minima mentioned below were put into effect. Bad weather accidents on Class II aircraft came down from 23 in 1941-1942 to an average figure of 5 yearly thereafter.

Class III (Figs. 7 and 8). The general low rate experienced in this class should be noted. This is probably because of the simplicity and reliability of this type of aircraft, but indicates that the difficulty of operating twin-engined aircraft *per se* may have been overstressed in the past. It is undoubtedly easier to handle twin-engined aircraft on the ground than to handle the majority of comparatively blind single-engined aircraft.

The sharp increase in the " not responsible " accident rate shown in the last year probably has no actuarial significance because of the severe drop in the number of deliveries occasioned by the speedy close of the War, which caused a single accident to exert undue influence on the rate.

Class IV (Figs. 9 and 10). The Class IV accident rate, although uniformly low, does not show the same downward trend as that attained in the other classes. It is likely, however, that, if A.T.A. had continued to function for another year, the Class IV accident rate would have shown a substantial decrease because of the increased production of jet aircraft. These aircraft, which were flown by ordinary Class IV pilots without any special instruction, were—from the pilot's point of view—much easier to operate, and technically more simple, than previous types.

Class V (Figs. 11 and 12). The very low rate of Class V accidents is specially noteworthy. On these aircraft the A.T.A. crew consisted of pilot and flight engineer, since controls were so placed that they could not all be reached from the pilot's seat. The flight engineer took over the majority of technical responsibility, leaving the pilot free to cope with flying problems pure and simple, and the increased size of these aircraft appeared to offer no difficulties at all in operation.

Class VI. The number of deliveries of Class VI aircraft never reached actuarial proportions, and no graph has been made.

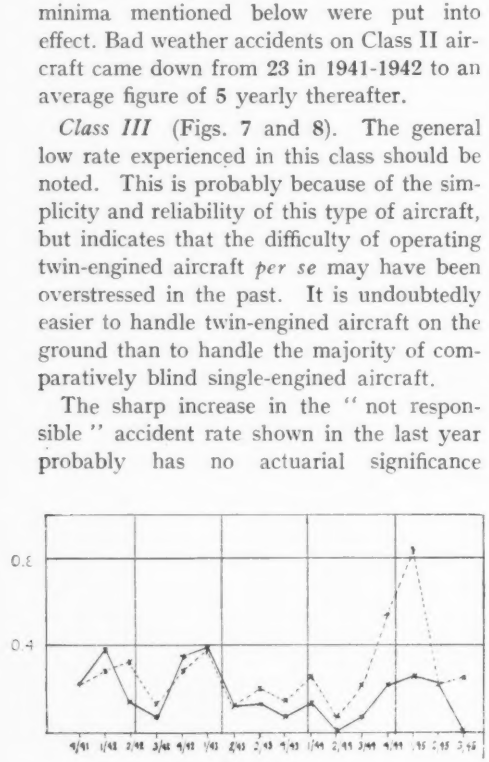

Fig. 7
Class III Aircraft Accident Rate (Quarterly)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -

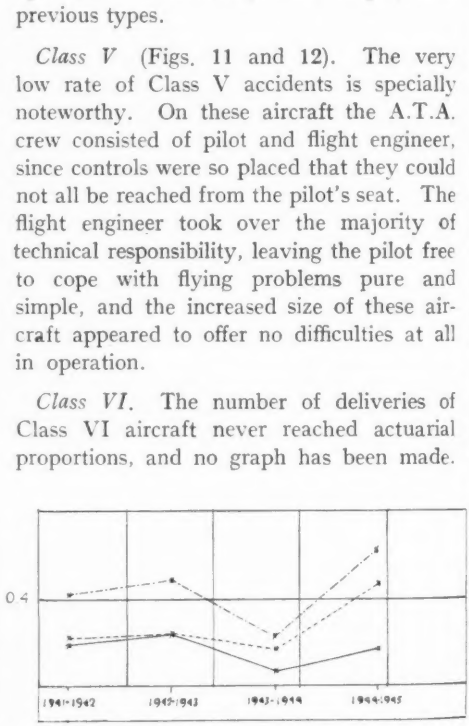

Fig. 8
Class III Aircraft Accident Rate
Yearly (Oct. 1st-Sept. 30th)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -
TOTAL - — - —

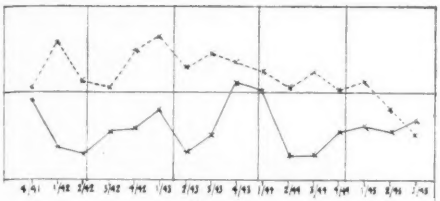

Fig. 9

Class IV Aircraft Accident Rates (Quarterly)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -

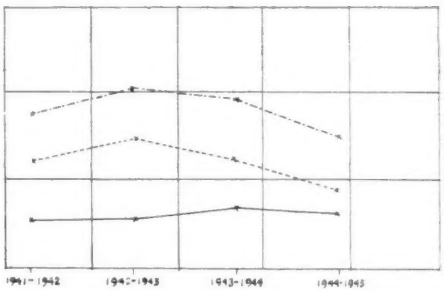

Fig. 10

Class IV Aircraft Accident Rates
Yearly (Oct. 1st-Sept. 30th)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -
TOTAL - — - —

It is of interest that when ferrying first began in **1943**, no less than five accidents occurred during the first **107** delivered. The majority of these were taxying accidents—grounding on sandspits, mistaking buoys, and the like. After this bad start the accident rate materially reduced, and only four other accidents occurred in the following two years. Seadrome control and equipment had not in **1943**, and have not to date, reached the same pitch of detailed and standardised efficiency as airfield control, and accordingly, A.T.A. pilots coming fresh to the work experienced taxying difficulties.

5. SPECIALISATION.

As will be seen above, A.T.A. policy was throughout largely directed towards the production of pilots who could fly all types of aircraft. Specialisation was confined to the splitting of aircraft into the six classes shown above, although from time to time additional specialisation was introduced by specifying intermediate classes, such as **2+**, covering special types such as the Walrus, or the Tomahawk, which were producing, or were considered to be likely to produce, particular difficulties.

The alternative policy of specialising pilots on one or two types only, was considered many times, and investigation indicated that such a policy might undoubtedly have produced a reduced accident rate. Against this had to be calculated the increased number of aircrew which such a policy would have involved. Complete specialisation might easily have required a trebling of the size of A.T.A., involving, of course, not only trebling the number of aircrew, but trebling the number or size of Ferry Pools, the number of taxi aircraft and the number of all ancillary personnel. Furthermore, many types were never produced in sufficient quantities to render true specialisation feasible. On balance, therefore, it was concluded defi-

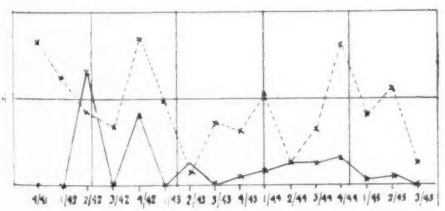

Fig. 11

Class V Aircraft Accident Rates (Quarterly)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -

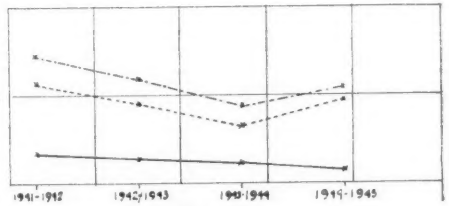

Fig. 12

Class V Aircraft Accident Rates
Yearly (Oct. 1st-Sept. 30th)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -
TOTAL - — - —

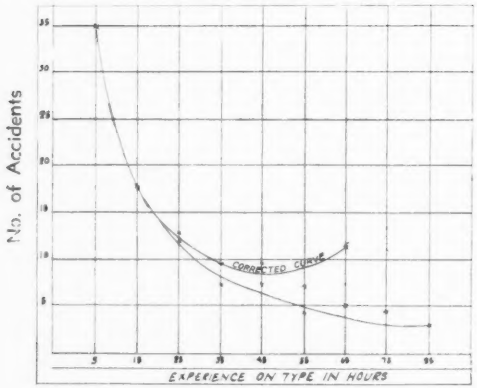

Fig. 13

Spitfire Accident Rate in Relation to Experience by Pilot on Type. A.T.A. Responsible.

nitely that the policy adopted was the most economical one in all the circumstances.

During investigations into this subject, analysis of the accident rate to pilots on their first flights on types new to them were taken out in two different ways. One method showed three accidents on 855 first flights on a type and on another, two accidents in 360 first flights on Spitfires. These two results confirmed one another and indicated that the accident rate on such flights was of the same order as the general accident rate during the first ten hours experience on a type. Since the average rate during the first ten hours proved rather higher than the average for all flights, there are grounds for believing that the rate on first flights was actually somewhat lower than during the subsequent odd nine hours experience.

On his first flight, an A.T.A. pilot carried the special A.T.A. Handling Notes produced by the A.T.A. Technical Department. On subsequent flights he usually only carried A.T.A. Ferry Pilots' Notes giving basic data on each type incorporated on a single card. On a first flight, an A.T.A. pilot was instructed not to ask for any outside assistance or advice, but to complete the flight solely on the A.T.A. book. This was necessary to ensure technical uniformity.

An analysis was also made in an attempt to demonstrate the effect of experience on a type on accident rates. An analysis of 210 Spitfire accidents during the two years 1942-1943 produced the curve shown in Fig. 13, but the falling off in the graph after 40 hours may be increasingly due to the small number of pilots who reached this stage of experience on a single type. A corrected curve is indicated in which an allowance is made for this. It tends to show that the accident rate probably did not decrease further, and may even increase, after 40 hours, perhaps because of the relative infrequency with which ferry pilots of that stage of experience ferried Spitfires.

This corrected graph was obtained by plotting the curve of "pilot not responsible" accidents on Spitfires and assuming that such accidents (mainly technical failures) were as likely to occur to a pilot at one stage of experience as at any other. The "pilot responsible" rate was then corrected by multiplying the number at each stage by the appropriate factor. The graph of "pilot not responsible" accidents on Spitfires over the period is also given in Fig. 14.

In addition an attempt was made to see if pilots with a greater total number of flying hours in their log books suffered a lower accident rate than those with less. The figure taken was 400 hours, and while the rate of pilots of over 400 hours' experience on their first ten hours on Spitfires was only half of that of pilots with less than 400 hours' total experience, after ten hours on the type, accident rates between the two classes of pilots

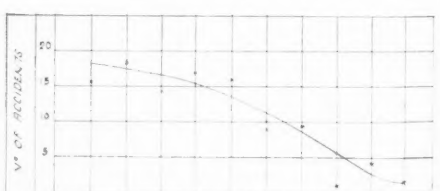

Fig. 14

Spitfire Accident Rate in Relation to Experience by pilot on type. A.T.A. Not Responsible.

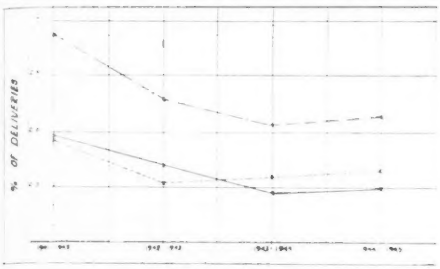

Fig. 15
Spitfire Accident Rate
Yearly (Oct. 1st-Sept. 30th)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -
TOTAL - — - —

were approximately the same. Fundamental intelligence appears to be more important than experience, and came to be so regarded by A.T.A.'s selection board.

An investigation was also made into the accident rate during 1943 on types of aircraft of which less than 1,000 were delivered during the year, and those on which deliveries were more than this figure. The following figures were the result, indicating that in general the accident rate was least on the commonest types of aircraft:

	No. of types	Pilot responsible accident rate
Single-engined types		
below 1,000	15	.75%
above 1,000	5	.29%
Twin-engined types		
below 1,000	18	.41%
above 1,000	6	.23%

On multi-engined types, the figures were too small to be significant.

6. Of all the various types of aircraft ferried by A.T.A., pride of place must undoubtedly be given to the Spitfire. This machine was ferried almost from the beginning, and many thousands were delivered. It probably had the least accident rate of any type handled by the organisation, and A.T.A. experience is illustrated graphically by Fig. 15. As will be seen, at the beginning the rate was somewhat high, but this rapidly came down. The reason for the initial high rate was due in the main to taxying accidents, collisions, nosing over, etc. The reason for the improvement is difficult to assess, but it is probably due to the unfailing insistence upon care while taxying.

The development of A.T.A. training may also have some bearing, as the initial pilots were passed hurriedly through a Central Flying School course, and some had as little as one hour's dual on a Battle and a Harvard before being let loose on all Service single-engined types. As the A.T.A. Schools developed and grew, training procedure was lengthened and tightened, and first Hurricanes and then Spitfires were added to the School fleet. It must be stated, however, that the Spitfire accident rate was materially reduced before School instruction on the type became available.

Figure 16 shows the Spitfire accident rates compared with the combined rates of three types which gave a certain amount of trouble.

Another example of a surprisingly low accident rate experienced on a type which might have been expected to produce diffi-

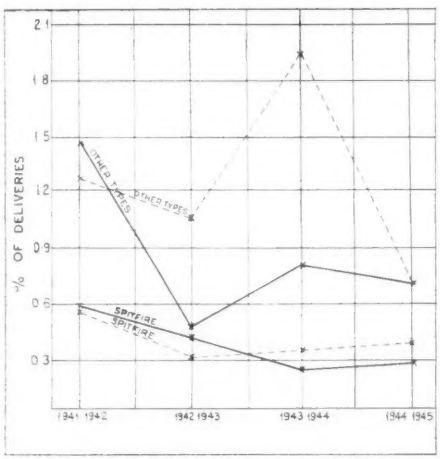

Fig. 16
Spitfire Accident Rate and Combined Accident Rate of Three Troublesome Types
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -

culties is the Mosquito (Fig. 17). Although the landing speed of this aircraft was high and the tendency to swing on take-off if throttles were opened too quickly was marked, the Mosquito accident rate was below the average for Class IV aircraft.

In both these cases the large numbers ferried probably had a bearing on the good results; nevertheless, they are a remarkable testimony to the aircraft concerned.

7. COMPARISON OF ACCIDENT RATES BETWEEN MEN AND WOMEN.

In attempting to compare the accident rates between men and women, many difficulties are manifest. To reduce the number of unknowns to a minimum, it was decided to take a Ferry Pool composed entirely of women and compare their rate per 100 " journeys " on Spitfires with the corresponding Spitfire rate experienced by a men's Pool situated in the same area. Over the whole period reviewed, *i.e* from January 1942 to September 1945 the difference in rate was only 0.02 per cent.

8. ENGINE FAILURES ON TAKE-OFF.

Engine failures on take-off, with their attendant risks, have recently been the subject of considerable attention from the design point of view, and stiff future requirements have been laid down accordingly. In A.T.A., with many hundreds of different marks and types of aircraft being constantly handled and maintained, such failures might have been expected to have been serious, but an investigation showed that their frequency came out at about 1.2 failures per 10,000 flights on ferry aircraft, and as low as one in 50,000 flights on taxi and School aircraft. It might be considered therefore that if, with peace-time maintenance standards, these results can be materially bettered, it is hardly economically worth while to prejudice efficiency of aircraft by laying down stiff design requirements.

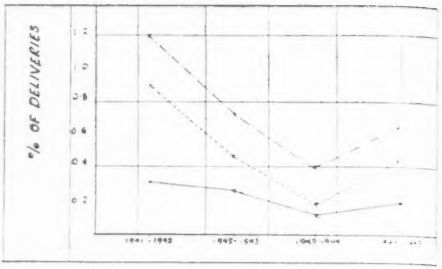

Fig. 17
Mosquito Accident Rate
Yearly (Oct. 1st-Sept. 30th)
A.T.A. Responsible ————
A.T.A. Not Responsible - - - - - -
TOTAL - — - —

9. THE RELATIVE RISK OF FIRE AFTER A CRASH RESULTING IN A TOTAL WRITE-OFF AS BETWEEN WOODEN AND METAL AIRCRAFT

An investigation into this problem was made and the figures were: wooden aircraft, total write-offs—40, burnt 4; others, total write-offs—129, burnt—41. The figures for wooden aircraft were rather small but, bearing this in mind, tend to show that the risk after write-off is three times as great in the case of a metal aircraft as in that of a wooden one.

10. ACCIDENT RECORD OF COMMUNICATIONS AIRCRAFT

A.T.A.'s taxi service approached more nearly than did its other work to the operations of a Charter airline. Air Movements Flight, established on 1st June, 1943, was in fact a Charter Service devoted solely to carrying non-A.T.A. passengers, freight, and ambulance cases.

For six years taxi aircraft at a moment's notice were despatched to destinations as widely spread as Belfast, the Hebrides, Land's End, and in the last year as far as Paris, Berlin, Oslo, Copenhagen, Marseilles, Naples and Cairo.

Total hours flown were approximately 150,000, mainly on Ansons and Fairchilds.

The Anson in particular proved to be one of those historic aircraft which, like the Spitfire, made its mark on the period.

Its characteristics were so free of vice and its engines so reliable that, although single-engined performance is poor, it produced an accident rate which it is believed has not often been bettered in full commercial airline work.

The following table gives approximate figures:—

Taxi Hours.
October, 1941—September, 1945.

Total taxi hours on all types and including Air Movements Flight...	146,076
Approximate Anson hours	73,000
Mileage in Ansons	9,859,000
Passenger miles in Ansons	49,275,000
Fatal accidents in Ansons	5
Fatalities in Ansons	8
(*i.e.*, 1 fatal accident per 14,600 hrs.)	

Air Movements Flight—Special Communications, Freight Work.

A.M.F. hours	21,000
Mileage in A.M.F.	2,835,000
Fatal accidents in A.M.F.	3
Fatalities in A.M.F. (aircrew)	5
(*i.e.*, 1 fatal accident per 7,000 hrs.)	
Fatalities in A.M.F. (passengers)	Nil

Anson on Ferry Taxi Work Only Over the Six Years, October, 1939—October, 1945.

Approximate hours	80,000
Approximate mileage	10,800,000
Seat passenger miles	54,000,000
Fatal accidents	3
Fatalities	4
(*i.e.* 1 fatal accident per 26,700 hours or 1 passenger fatality in 54,000,000 passenger miles.)	

11. RELATIVE RELIABILITY OF LIQUID-COOLED AND AIR-COOLED ENGINES

An investigation into this subject revealed that over the four-year period approximately 187,000 liquid-cooled and 253,000 air-cooled engines were handled. Four hundred and forty-six engine defects leading to reportable occurrences were analysed and the resultant figures corrected to allow for the difference in relative numbers handled. The results are tabulated in Appendix V. The total figures indicate that the relative defects were almost exactly equal in proportion.

Mechanical defects and those due to carburation and ignition were greater for air-cooled than for liquid-cooled engines, but the balance was restored by the coolant defects which could only occur on the latter type of engine. Mechanical defects caused by hydraulicing* were only experienced on air-cooled engines. It will be noticed that in the second two-year period the number of coolant defects experienced on liquid-cooled engines was greatly reduced, probably because of the use of two-piece cylinder blocks.

Snags which did not lead to a reportable occurrence could not be recorded, so the relative cost of maintenance cannot be clearly assessed from this table. However, the combined figures for reportable occurrences due to bad maintenance or servicing show approximately the same result for either type of engine.

The headings "Mechanical" and "Lubrication" defects are probably more accurately combined, since in many cases of, *e.g.* bearing failure it was impossible to discover whether the bearing failed mechanically or whether the failure was primarily due to lubrication defect.

12. THE RELATIONSHIP BETWEEN PILOTS' SELECTION (CLASSIFICATION) AND THE FATAL ACCIDENT RATE

When going through the A.T.A. selection board, acceptable pilots were medically classified into three main groups, A, B and C:—

A. Pilots who were considered by medical (physical, psychological and aptitude) standards likely to become good ferry pilots.

*A war-time term used to infer the results of trying to start an engine when one of the cylinders is filled with fuel or oil—usually one of the inverted cylinders or sleeves in a radial engine.

B. Those pilots who were considered to be about average.

C. The lowest acceptable classification, which included the less apt pilot material.

A full technical description of the A.T.A. medical selection system is outside the scope of this paper, but it should be mentioned that particular emphasis was placed on mental and psychological factors, as against the purely physical side. Emphasis on psychological and aptitude standards produced the surprising result that the average A.T.A. classification of all physically defective pilots was slightly higher than the average category of all other pilots. Although A.T.A. had many crippled and physically maimed pilots, these proved on the whole more careful and their accident rate was actually lower than that of their more normal brethren. The success of the methods of classification adopted is indicated by the following figures showing fatal accidents apportioned between the three different categories of pilot:—

Category A, 9 per cent.; Category B, 23 per cent.; Category C, 68 per cent.

13. RELATIONSHIP BETWEEN PILOT AGE GROUPS AND ACCIDENT RATE

The average age of all A.T.A. pilots was found to be about 34 years. An investigation was made into the proportion of all " pilot responsible " accidents suffered by pilots above and below this age and over the period July, 1943, to June, 1945, it was found that pilots below 34 years of age were responsible for 58 per cent. and pilots above for 42 per cent. of all accidents.

As this review was taken over a period of two years, the age assessment was calculated as that in force in June, 1944.

14. MAINTENANCE OF PILOTS

From February to June, 1942, the experiment was made at one Ferry Pool whereby every pilot was seen every morning by a medical officer. In most cases this was limited to a brief chat between the pilot and the doctor when the former was signing the register in the morning. Some unexpected conditions were discovered during these informal morning chats. Occasionally a pilot was found not fit, although he considered that he had perhaps only a slight cold. As a result the sickness rate in the unit concerned during the period was naturally higher than normal. Although the figures involved are too small to be really reliable, it is a fact that the accident rate steadily decreased over this experiment.

What is, however, important is to note that on several occasions pilots were prevented from flying because of unfitness, of which they were entirely unaware.

15. TRAINING METHODS

A detailed account of the highly specialised training methods evolved in A.T.A. is outside the scope of this paper. The general principle, however, was to exclude rigorously all non-relevant subjects, such as radio, blind-flying, handling of armaments, etc., and to concentrate on presenting the essentials in the simplest possible way.

By the exigencies of war, refresher courses could only be given every other year to each pilot and flight engineer, and it was noticeable that the technique of each had seriously deteriorated in as many as 80 per cent of all cases during this period.

16. GENERAL

Although it is impossible to prove the following by figures, A.T.A. were fully convinced that the satisfactory welfare of all concerned in a flying organisation, and all other similar factors contributing to good morale, have a large bearing on the accident rate.

Thus the efficiency of every department of a flying organisation has a bearing on this subject.

Fig. 18
Taxying Accident Rate (Quarterly)
A.T.A. Responsible ——————
A.T.A. Not Responsible - - - - - -

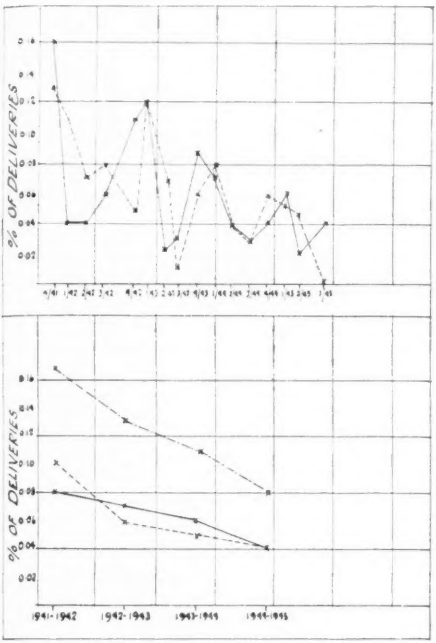

Fig. 19
Taxying Accident Rate
Yearly (Oct. 1st-Sept. 30th)
A.T.A. Responsible ——————
A.T.A. Not Responsible - - - - - -
TOTAL - — - —

PART III

In the third part of this paper various particular accident problems are recorded which arose during the course of operations and the remedial steps taken, in accordance with the general principles outlined in Part I.

1. TAXYING ACCIDENTS

Taxying accidents, like the poor, were always with us, and especially in war-time will always constitute a particularly annoying proportion of total accidents. A graph of the taxying accident rate is given in Figs. 18 and 19. This is based on "journeys" because these increased very greatly in winter as opposed to summer conditions, and in taxying accidents it is particularly true that not more than one accident can be experienced in one sortie. The winter increase mentioned is noteworthy but it is also interesting that the measures taken resulted in a general downward trend in the rate over the period under review.

Taxying accidents due to collision remained approximately the same throughout each quarter of the year; those due to bad airfield surface or high winds increased during the winter months. It must be remembered that during the war many airfields were put into use at an early stage of construction and pilots had to negotiate obstructions and operate in conditions which would not be tolerated in peace-time.

Remedial Action. Remedial action regarding taxying accidents clearly divides itself into two parts. In the first, a constant campaign has to be undertaken with airfield and flying control authorities, both in general matters and in particular cases of unwarranted obstructions, etc. In the second, all possible steps must be taken with pilots to tighten up discipline.

Taxying accidents in A.T.A were regarded as serious misdemeanours and the offender was liable to be dealt with with corresponding severity. The most trivial incident was reported, even one resulting in no damage to the aircraft. The line taken was that, generally speaking, there was hardly any excuse for a taxying accident, for if at any time any doubt should enter the pilot's mind, he could always stop his aircraft, get out for a look round, or call for assistance. Pilots, therefore, were held "responsible" or "to blame" for taxying accidents unless there were an unusual number of mitigating circumstances. The Accidents Committee's findings would then be reported to the Chief Operations Officer, who would then, in a large number of cases, institute disciplinary action. Taxying accidents proved almost the only category

of accident in which the major cure was considered to lie in the field of punishment. (Appendix I, paras. 4 and 5.)

Full information and special bulletins on taxying accidents were issued from time to time, and information as to aerodromes where taxying accidents occurred most frequently.

The downward trend of the resultant rate indicates that these measures were justified.

2. TECHNICAL DISCIPLINE

In the early months of A.T.A., pilots would be sent to collect machines which they had never seen before and without any technical information beyond that which could be gleaned from a hasty glance at Air Ministry notes if they were available; sometimes types would come on ferrying for which Air Ministry notes had not yet been produced. Naturally this situation provoked a number of accidents.

Remedial Action. Remedial measures covered the whole field of technical publications, instruction and discipline. As soon as possible, A.T.A. established their own Technical Department whose job it was to produce Pilots' Notes especially for ferry pilots, in a concise and easily understandable form. The matter published was based on the various technical courses given in A.T.A. schools and the Technical Department collaborated with the Director of Training in the production of the necessary syllabi. The basic principle was to produce the simplest and clearest possible instructions and cut out all unnecessary matter. (Appendix I, paras. 8 and 9.)

Technical discipline was constantly watched, and occasionally checks were instituted. Thus at one period there was an outbreak of defects reported which might have been due to incorrect engine stopping procedure on the part of pilots or flight engineers. A date was promulgated when an official check would be taken at all transit pools on all aircraft arriving, and after this check had been taken pilots were advised that an unannounced check would take place later. Technical instructions regarding the stopping procedure to be adopted for the comparatively few different engines in use were constantly revised and kept up to date.

Another important matter was the eradication, so far as possible, of the traditional non-co-operation between ground and aircrews. Such methods as combined meetings and social events which both attended went some way towards improving the situation. In addition, various bulletins were issued to both pilots and ground crews illustrating the relative difficulties of each other's job and how these could be eased by each following the correct procedure.

A constant campaign was maintained to ensure that pilots punctiliously carried out all pre- and post-flight " paper work." In particular, all concerned were impressed that verbal snag reports almost always led to trouble. At a fairly early stage the system was adopted of all ferry aircraft delivery chits incorporating a snag report which was written out and handed to the consignee, the pilot bringing home a copy on the back of his acceptance chit. These snag reports were then collated and recurring defects which showed up were referred either to A.T.A.'s controlling R.A.F. Group, if an R.A.F. aircraft was involved, or to A.I.D. if a contractor's aircraft was involved. (Appendix I, paras. 6 and 7.)

3. FATAL ACCIDENTS (Appendix IV.)

The graph of A.T.A. fatal accidents, Fig. 20, shows that the rate came down from one fatal accident per 1,735 deliveries in the year 1941-1942, to one in 3,887 in the year 1944-1945. It is not useful to consider the relationship between " responsible " and " not responsible " fatalities because by the nature of things, many fatal accidents involved a finding of " insufficient evidence." Of the 103 fatal accidents which

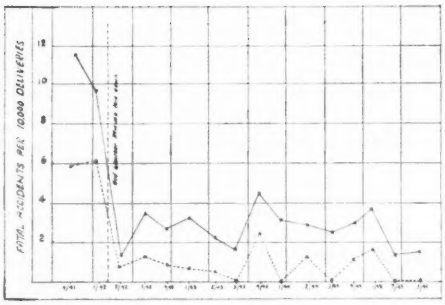

Fig. 20
Fatal Accident Rates on Delivery Aircraft (Quarterly)
A.T.A. Responsible ————
Other - - - - - -
(Vertical dotted line shows bad weather minima laid down.)

occurred, 53 pilots were "apparently responsible," 20 "not responsible" and in the remaining 30 there was insufficient evidence to assess responsibility. The term "apparent responsibility" was invariably used in fatal accidents since the pilot was not able to appear to give direct evidence.

Remedial Action. Remedial action regarding fatal accidents was, of course, pursued over the whole field, but the largest single factor leading to fatal accidents was bad weather. Fig. 20 shows a sudden drop in this type of accident in the early months of 1942.

In early 1942 bad weather fatalities had reached a peak and the step was taken of laying down weather minima, below which pilots were not permitted to fly. In general, pilots were instructed not to fly in conditions where the horizontal visibility was less than 2,000 yards and the cloud base less than 800 feet. These conditions were absolute minima, and did not relieve the pilot of the responsibility of landing if the prevailing conditions made it, in his judgment, unsafe to proceed. The actual order issued is copied in Appendix I, para. 1.

In addition, meteorological stations were set up at all Ferry Pools and with the close co-operation of Air Ministry, presentation of meteorological data was modified especially to suit the requirements of pilots confined to contact navigation.

The problem of whether or not to give pilots additional blind-flying instruction was frequently considered, but the conclusion was reached that such instruction was not compatible with the bad weather minima laid down, and if it were given it would merely act as a temptation to break these orders. Furthermore, it was considered impossible to train pilots to blind-fly all types of aircraft indiscriminately. In addition, blind-flying could only be done safely if coupled with the use of radio facilities and these, designed for the use of ferry pilots not confined to flying any particular route or in any particular area, were not available.

When, in the closing months of the period ferrying to the Continent was undertaken, the use of radio was laid down as a requirement by the Commands concerned. The figures of aircraft ferried to the Continent were never really large enough to show any clear results, but so far as they went, they did not show any improvement on the results attained by pure contact navigation. This does not, of course, attempt to show that radio navigational aids are useless, but appears to indicate that they are of little assistance to all-type ferry pilots flying different routes and aircraft every day.

4. One or two problems arose which completely defeated efforts at analysis. As an example, over a considerable period analysis was taken of the fatal accident rate experienced on each day of the week. At first the resultant graph showed a big peak experienced on Saturdays and Sundays, with an almost negligible rate on Mondays. Ferry pilots' periods of duty were intentionally split up into units of fifteen days, consisting of twelve days on and three days off in the summer and thirteen days on and two days off in the winter. Thus their leave days fell on different days of the week each time and week-end duties and facilities were

indistinguishable from those of other days. In fact the busy ferry pilot would frequently not have been aware what day of the week it was. One eventually was tempted to ascribe this state of affairs to Divine Wrath, although only superficial consideration was needed to conclude that during the period under review Sunday ferrying was far from the greatest of sabbatical infractions.

Analysis over a still longer period showed that the period from Thursday to Sunday inclusive, proved the dangerous days with only fractional risks of fatalities occurring between Monday and Wednesday. This result snatched away even the above straw and the problem remains unsolved.

A similar investigation for the year 1943 was made into the likelihood of taxying accidents occurring at different times of the day, and the following table shows the result:—

	Before 12.00	12.00 14.00	14.00 16.00	After 16.00	Total
Ferry Aircraft					
S.E. Take-off	5	3	16	3	27
Landing	4	3	3	2	12
T.E. Take-off	3	1	4	2	10
Landing	1	4	2	2	9
M.E. Take-off	0	0	1	1	2
Landing	0	0	0	0	0
Total					
Take-off	8	4	21	6	39
Landing	5	7	5	4	21
Taxi Aircraft					
S.E. Take-off	2	0	1	1	4
Landing	0	1	1	3	5
T.E. Take-off	2	0	1	0	3
Landing	0	0	4	0	4
Training Aircraft					
Take-off	1	1	1	1	4
Landing	0	1	0	0	1
Totals					
Take-off	13	5	24	8	50
Landing	5	9	10	7	31

The conclusion which stands out is the relatively high frequency of accidents to ferry aircraft before take-off after lunch, *i.e.*, after 14.00 hours.

Single-engined aicraft accounted for the greater number of these accidents. The taxying accidents to twin- and multi-engined ferry aircraft were small and fairly evenly spread, as also, in general, were those to taxi and school aircraft. Their distribution is without much significance except perhaps in the case of the taxi aircraft which manifest the same tendency as the single-engined ferry aircraft to have more accidents after 14.00 hours than before, namely in the proportion of 11 to 5.

The taxying accidents to ferry aircraft for which pilots were held "*not* responsible" were fairly evenly spread, as the following shows:—

	Before 14.00 hrs.	After 14.00 hrs.
Before take-off	10	11
After landing	10	9

The figures, though small, lead to the conclusion that post-prandial somnolence is a risk worth taking into account in aviation as well as in other fields of endeavour.

Remedial Action. The main remedial action available is clearly to publish these facts for the attention of all aircrew. As a further step, permission was laboriously negotiated with the Ministry concerned for a supply of chocolate to be issued to aircrew before take-off so that they could stave off the pangs of hunger during the day and so avoid the temptation of indulging in heavy meals between flights.

5. ACCIDENTS OCCURRING IN PAIRS

In January, 1942, it was noticed that accidents involving one pilot were frequently occurring in pairs over a short period. The frequency of these double accidents was the subject of considerable investigation. It was found that when a pilot had an accident and was not medically examined carefully (with particular reference to the psychological aspect) he was prone to experiencing another accident within a period of one month. Over the six-month period from June 28, 1941, to January 6, 1942, 32 pilots were involved in 67 accidents occurring in doubles or trebles

within the above time limit. Twenty-five of these accidents were found to be due to pilot's error and of these 25 cases, in 9 the pilot was held responsible in the first accident, in 14 in the second accident, and in one pair for both accidents.

These 32 double or treble cases were further broken down as follows:—

Description	*No.*	*Likely bearing on the problem*
(i) Accidents completely dissimilar in nature ...	7	Possible
(ii) No similarity except bad handling of aircraft by unskilful pilot	1	Possible
(iii) Clear mishandling by pilot's C.O. who gave him another similar job immediately after being responsible for an accident	2	Very probable
(iv) In both or all accidents pilot held not responsible	9	None
(v) In the latter accident pilot held not responsible	5	Unlikely
(vi) In the earlier accident pilot held not responsible and in which physical injury or serious damage occurred	6	Very probable
(vii) Earlier accident resulted in slight damage and no injury	2	Very probable

In discussing this problem it is helpful to bear in mind that the old theory that after an accident it is psychologically necessary immediately to send up the pilot again if he is not to lose his nerve is now proven a fallacy.

It is interesting to note the marked increase in pilot responsibility in the second or subsequent accident. The whole investigation strongly indicated that every pilot is affected in some degree by any accident, however trivial, in which he is involved, and often the pilot is the least capable assessor of the degree to which he is affected.

Remedial Action. As a result of this investigation the procedure of medically classifying pilots after every accident, described in Part I, was put into force. No pilot who had been involved in other than the most trivial accident was permitted to fly again before he had been examined by a medical officer who was especially trained in aviation medicine and who was qualified to recognise and treat this particular psychological trauma. It was found that the maximum evidence of this injury manifests itself about the third or fourth day after the accident.

After this procedure was instituted accidents in pairs were greatly reduced, and whereas in the six months reviewed above an average of three cases occurred monthly in which the pilot was found " responsible " for an accident within one month of a previous occurrence, in the following forty-two months just under one similar case occurred monthly.

CONCLUSION

To conclude this report a graph of "A.T.A. Responsible " accidents over the four years under review is presented in a slightly different form on a twelve-monthly basis. (Fig. 21.) This graph epitomises the result of six years' hard labour constantly directed towards the goal of prevention of accidents.

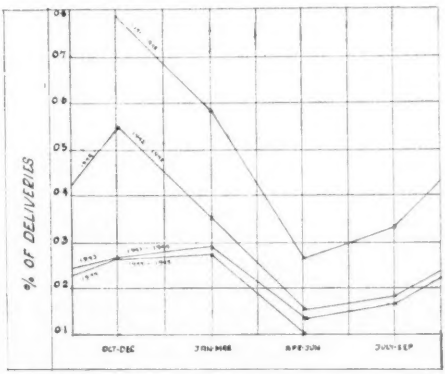

Fig. 21
Accident Rate—A.T.A. Responsible
Shown separately for each year.
Quarterly (Oct 1st-Dec. 31st, etc.)

APPENDICES

ORDERS AND INFORMATION MADE AVAILABLE TO ALL AIRCREW IN A.T.A. STANDING ORDER BOOK

1. *Bad weather flying restrictions laid down by A.T.A. an 6th April,* 1942. (Part III.)
   (i) Bad weather flying is strictly prohibited unless, for special operational reasons, a departure from this regulation is authorised (see (vii) below). ...
   (ii) Competition between pilots is strictly prohibited. The idea that, if A gets through and B does not, this is a reflection on B, is quite erroneous.
   (iii) No flight shall be commenced unless at the place of departure the cloud base is at least 800 feet and the horizontal visibility at least 2,000 yards. No flight over land shall be continued in conditions less favourable than the aforesaid, nor over the sea in conditions of less than 1,000 feet cloud base and 2,000 yards horizontal visibility.
   (iv) Flying in or above cloud, mist or fog and out of sight of the ground or sea is forbidden.
   (v) If the weather forecast is doubtful but the local weather clear, a pilot should start but if he encounters weather conditions worse than those specified in (iii) above, he will either adopt an alternative route or return and land at a suitable airfield.
   (vi) The above limits are absolute minima and do not relieve pilots of the responsibility of ensuring that they do not fly in conditions which are beyond their individual capabilities.
   (vii) Priority 1.W. aircraft, and in some cases Priority 1.S. aircraft, are not subject to the above limits, and pilots instructed to ferry them may use their own discretion.
   (viii) Air Movements Flight pilots, with instrument ratings on their Authorisation Cards, when flying aircraft equipped with wireless (other than short range sets) are not subject to the above weather limitations. They may use their own discretion as to the weather conditions in which they fly, except when flying passengers for Transport Command. On those flights they are subject to the same control as are R.A.F. pilots on the same work.
2. *Notes for pilots on the purpose and methods of the Accidents Committee.* (Part I).
   (a) The major purpose of the Accidents Committee is the prevention of further accidents, or a reduction in the accident rate. The aim of aircrew members and all other persons concerned with flying is, of course, identical. It is essential that this should be borne in mind since the Committee is enormously prejudiced in the discharge of its duties, if it is regarded as a punitive court whose main object is to find someone to blame for every accident.
   (b) To reduce accidents it is necessary to get at their root causes, and with this purpose the Committee acts as follows:—
      (i) It lays down regulations for obtaining evidence to enable the cause of each accident to be decided.
      (ii) It investigates each accident as fully as possible.
      (iii) On reaching conclusions as to the cause or causes of an accident, after they have been submitted to O.C., A.T.A., for his agreement, it publishes the findings as follows:
         A. To all aircrew for their information.
         B. In the event of a technical defect, to the authorities responsible for taking action to guard against a recurrence of the defect.
         C. In the event of poor aerodrome control or maintenance, to the authorities responsible for remedying defects of the type that contributed to the accident.
      (iv) It then follows up consequential action under B and C above.
   (c) While any person concerned in an accident has the right to attend the meeting of the Committee considering his case, the Committee does not itself request the presence of such a person at its meeting except in those cases when it is considered that he is likely to be able to give information to the Committee which is not provided in the written evidence submitted or obtainable from other sources, such as meteorological reports, plans of airfields, maps and technical publications.
   If the causes of the accident appear to be ascertainable from these, the person concerned is not called, as it is considered undesirable unnecessarily to take him from his normal duties.
   (d) The Accidents Committee apportions responsibility under the following headings:—
      (i) Pilot (or person concerned) not responsible and commended.
      (ii) Pilot (or person concerned) not responsible.
      (iii) Pilot (or person concerned) responsible.
      (iv) Pilot (or person concerned) to blame.
      (v) Insufficient evidence to determine responsibility.
   (e) It is important to underline the meanings of the words "responsible" and "blame" as used by the Committee. "Responsibility" is used in general when it is considered that an accident was caused by an error of judgment. In such cases the person concerned may for his own protection need a refresher course, a flight check or possibly a medical check. These are preventative and not disciplinary measures.
   "Blame," however, is assessed when it is considered that an accident has been caused by the disregard of an order or

negligence, and this is a reflection both on the sense of discipline and the capability of the person concerned.

(f) It should be underlined that the amount of damage done in an accident has little bearing on its importance. This very frequently depends purely on luck. As an instance, if a pilot, through neglect, mismanages his petrol cocks and loses his engine, he may then get down without damage or he may crash and destroy his aircraft. In either case he is equally negligent and so equally blameworthy. Similarly, successive failures of the same aircraft component may result in one case in a forced landing without damage and in another case in a crash. The importance of preventing a recurrence of this failure is just as great in both cases.

(g) The findings of the Committee on a given accident are forwarded to the C.O. of the person concerned and handed by him to the latter with advice that if they are considered inaccurate or unjust, a re-examination of the accident by the Committee *must* be requested. This is because a faulty finding of the Committee must reflect adversely on its reputation and therefore on its potential value in preventing accidents. The worst possible result of the Committee's consideration of an accident is for the person concerned to feel that he has been unfairly treated and instead of applying for a re-investigation to grumble among his fellows on the subject.

(h) If, after an appeal, the Committee does not alter its findings and the person concerned still feels that it is an error, he should make a further appeal through his C.O. to the O.C., A.T.A.

3. *Medical examination after an accident.* (Part I and III).

Any member of an aircrew involved in an accident or forced landing, however slight, must report to an A.T.A. Medical Officer, approved civilian medical practitioner or R.A.F. Station Medical Officer of the Station to which he is attached, and must undergo a medical examination and produce a medical certificate before he is allowed to fly again. An exception to this is when a Pool C.O., under powers conferred on him by the Accident Green Book, para. 73, sub-para. 12, categorises a pilot " A."

4. *Accidents resulting from misdirection of pilots.* (Part III).

The pilot is in all instances held responsible for the safety of his aircraft; whether in the matter of taxying an aircraft or stopping/starting an engine, signals or advice from ground staff must not be accepted as orders.

5. *Taxying accidents.* (Part III).

When a pilot is held to blame for a taxying accident, O.Cs. Units will take disciplinary action, which may range from an admonition to a Disciplinary Offence Report in the normal manner, bearing in mind the seriousness of the offence and the past record of the pilot.

6. *Completion of Snag Report forms.* (Part III).

A pilot must, in all cases, complete A.T.A. Snag Report Form (last page of collection chit) and hand it to the recipient of the aircraft. Where an aircraft is transited at an A.T.A. Pool, Snag Report must be handed to the Ground Engineer before the pilot leaves the aircraft. Nil reports must also be signified. Full particulars regarding consignor, consignee, etc., must be given, also duplicate Snag Report Form on back of delivery receipt must be completed.

Every defect observed by a pilot, however trivial, must be recorded on the Snag Report. In addition, any heavy landing must be entered, *i.e.*, any landing which is abnormal as regards touch down, drift on touch down or behaviour during landing run. Cases where aircraft have had to be started on their batteries must be recorded, and also cases where ballast has, for any purpose, been removed or added to the aircraft during the flight in question.

7. *Taxi aircraft—flight/snag sheets.* (Part III).

Taxi pilots (*i.e.*, pilot shown on top of the taxi sheet) must, before leaving the aircraft, correctly fill up the taxi flight sheet, record any snags or fuel uplifts thereon, sign it and leave it inside the Form 700 whose correct location is, in the case of an Anson, the rack behind the pilot's seat, and of a Fairchild, in the locker on the right-hand side of the instrument panel.

8. *Technical information.* (Part III).

The following four sources of technical information are available to pilots and must be used as follows:—

(i) A.T.A. Handling Notes and Air Ministry Pilots' Notes.
When the pilot is flying a type or mark for the first time, or one with which he is not fully familiar, A.T.A. Handling Notes give full instructions on the type. One or other of these publications must be taken by the pilot on such flight, and carefully read before take-off. This is also necessary if a familiar type is flown after an interval of some weeks.

(ii) Ferry Pilots' Notes.
When flying an aircraft with which the pilot is familiar these serve the purpose of an *aide memoire*, and must be carried at all times by pilots while ferrying. They provide sufficient data to remind the pilot of the lay-out and technical details of the machine he is ferrying.

(iii) Technical Instructions.
These are contained in the Technical Instruction Book, which is a loose-leaf book available in the Pilots' Rest Room at all Units. These books contain last-minute instructions or alterations which have come out subsequent to the publication of Handling Notes. It is, therefore, essential that pilots should refer to this book constantly, even when ferrying aircraft with which they are well acquainted.
In addition, the Technical Instruction Book contains articles giving general information of assistance to pilots.

(iv) Pilots' Reminder Book.
Pilots are required to read and to act in accordance with the information given in " A.T.A. Pilots' Reminder Book, Second

Edition," which is issued personally to them.

9. *Accident Procedure for Pilots laid down in Ferry Pilots' Notes.*

SUMMARY OF IMMEDIATE ACTION

to be taken after an accident or forced landing.

FIRST

1. Note the TIME, and POSITION on map.
2. Get responsible person to GUARD the aircraft and ask him to make list of EYEWITNESSES, while you—
3. TELEPHONE watch office at Service aerodrome or A.T.A. Operations Room, whichever is nearer, and—
4. State: WHERE YOU ARE and what passengers you have, DAMAGE and INJURIES caused.
   Ask for: your DESTINATION TO BE INFORMED IMMEDIATELY, if you were signalled out, and
   a GUARD for the aircraft.
   Arrange TRANSPORT to collect you.

NEXT, before finally leaving the scene of the occurrence—

5. Ensure that GUNS ARE UNLOADED before aircraft is otherwise touched.
6. Endeavour to obtain written REPORTS from at least two reliable EYEWITNESSES.
7. Take possession of LOG BOOKS and loose equipment (if any).
8. Collect more complete INFORMATION on DAMAGE, etc., particulars for SKETCH PLAN and so on. Also note any DAMAGE TO PROPERTY and name and address of owner. Even when no damage, note owner's name.
9. Make sure the aircraft is left IN COMPETENT HANDS and SECURED against damage from wind or rain.
10. REPORT to Duty Pilot at Service aerodrome or Operations Officer (A.T.A.) and carry out reporting and other responsibilities as set forth in full on reverse side of this card.

NOTE: If you have landed undamaged outside an aerodrome, you may not take off without the authority of your C.O. or his deputy.

SUBSEQUENT ACTION

1. Report to the Station Duty Pilot or A.T.A. Operations Officer and give the following information:—
   (a) Aircraft — Type, Mark, Number; Engine(s)—Type and Number (see Log Books); and if any secret equipment. Also Engine(s) and Airframe hours.
   (b) The unit owning the aircraft (if a ferried aircraft, the Consignor and Consignee, shown on your delivery chit).
   (c) Purpose of flight, *e.g.*, ferrying from ——— to ———; training flight, etc.
   (d) Full details of names, units and injuries of all personnel.
   (e) All possible information regarding extent of damage, and the cause of the accident or forced landing, including weather information.

   These particulars are also required attached to the pilot's report outlined in para. 7 below.
2. Ensure that a signal is sent reporting the accident to your destination, your Ferry Pool, and (if ferried aircraft) H.Q., 41 Group. Then telephone your Pool.
3. Hand over Log Books and loose equipment to a competent officer and obtain a signature on your delivery chit.
4. Obtain a report, if relevant, from (a) an officer representing the Station Commander on any defects of the aerodrome surface or airfield control, and (b) from an engineer officer, after examination of the aircraft, on any technical defect discovered. Tell him everything which will help his investigation. Make out a snag report if necessary and give him the top copy.
5. In most accidents a *sketch plan* must be made showing such details as compass points, wind direction and velocity, runways and perimeter track, bad ground marked or unmarked, and course followed by the aircraft in the air or on the ground. If possible, have this plan endorsed by a witness.
6. DO NOT LEAVE THE STATION UNTIL RELEASED BY THE STATION COMMANDER OR HIS DEPUTY.
7. A written report on the occurrence must be made to your C.O., and eyewitness reports, sketch plan, details of damage to property, etc., detailed above, attached. If a written report has been made to a C.O. other than your own, a copy of this must also be attached.

   Flight Engineers must make an independent report of the circumstances and relevant technical details.

Appendix II

AIR TRANSPORT AUXILIARY
HEADQUARTERS ACCIDENTS COMMITTEE

FINDING

Date of Finding: 28th March 1945.
Acc. Ref. No., Pilot: 17FP/ACC/234 Flt/Capt. A. N. Other.
Aircraft, Place, Date: Temptress V ZY.321 Langbrook 20.3.45
Subject: Whilst attempting to start the aircraft, a member of the ground crew was injured.
Cause: Incorrect starting drill being followed by both the pilot and the ground crew.
Responsibility: Both the pilot and the ground crew are held to blame for this accident.
Recommendation: 1) The attention of C.O.O. is drawn to this accident.
2) The attention of Chief Overseer, M.A.P., is drawn to this accident and to the necessity that all ground crews concerned with the starting of Temptress aircraft understand and carry out the correct starting drill. If this has not been previously done, it is recommended that the necessary instructions are immediately promulgated to the ground handling personnel of all contractors concerned.

P. A. Wills **S/Commander**
Chairman, Accidents Committee.

To:
Commanding Officer, A.T.A.
C.O.O. for C.Est.O.
Air Ministry, P.A.2.
M.A.P. for **D.G.A.D.**

O.C. No. 17 F.P.
Chief Overseer, M.A.P.
Flt/Capt. A. N. Other

AIR TRANSPORT AUXILIARY
HEADQUARTERS ACCIDENTS COMMITTEE

FINDING

Date of Finding: 18th July 1945
Acc. Ref. No., Pilot: 19FP/ACC/123 F O J. Blank
Aircraft, Place, Date: Seafish II YZ.456 Little Binding-in-the-Marsh 8.7.45.
Subject: The aircraft was forced landed at an airfield, without damage.
Cause: Failure of a hydraulic pipe in the cockpit, resulting in the pilot being sprayed with a large quantity of hydraulic fluid. Subsequent technical investigation indicated the failure was due to the end of a pipe-line being incorrectly belled prior to assembly.
Responsibility: The pilot is held not responsible for this forced landing.
Recommendation: The attention of D.T.D., M.A.P., and of Inspector i/c A.I.D., is drawn to this accident in the light of five similar previous accidents. It is strongly recommended that urgent action is taken either to remedy these defects or to redesign the system.

P. A. Wills **S/Commander**
Chairman, Accidents Committee.

To:
Commanding Officer, A.T.A. O.C. No. 19 F.P.
C.O.O. for C.Est.O. D.T.D., M.A.P.
Air Ministry, P.A.2. Inspector i/c A.I.D.
M.A.P. for D.G.A.D. F/O J. Blank

Appendix IV (Part III)

ANALYSIS OF FATAL ACCIDENTS

	No. Accs.	X	Y	Z	Tech.	Weather	Low flying & aerobatics	Cockpit drill	Bad airmanship	Others
1941										
4th Qtr.	14	9	0	5	2	7	1	0	3	1
1942										
1st Qtr.	12	6	1	5	2	7	0	0	2	1
2nd ,,	4	4	0	0	0	1	1	0	2	0
3rd ,,	7	3	1	3	2	2	0	1	1	1
4th ,,	5	3	1	1	1	1	0	1	2	0
Total	28	16	3	9	5	11	1	2	7	2
1943										
1st Qtr.	5	2	2	1	3	1	0	0	1	0
2nd ,,	5	1	3	1	2	1	0	1	1	0
3rd ,,	5	3	2	0	2	0	0	1	2	0
4th ,,	7	5	1	1	2	4	0	0	1	0
Total	22	11	8	3	9	6	0	2	5	0
1944										
1st Qtr.	7	3	3	1	2	0	1	1	2	1
2nd ,,	7	2	0	5	1	4	0	0	2	0
3rd ,,	7	3	2	2	2	0	3	0	0	2
4th ,,	5	2	2	1	1	2	0	0	1	1
Total	26	10	7	9	6	6	4	1	5	4
1945										
1st Qtr.	8	5	2	1	0	3	2	0	1	2
2nd ,,	4	2	0	2	0	0	1	1	1	1
3rd ,,	1	0	0	1	0	0	0	0	0	0
Total	13	7	2	4	1	3	3	1	2	3
Grand Total	103	53	20	30	23	33	9	6	22	10

Appendix V (Part II)

ANALYSIS OF DEFECTS IN LIQUID-COOLED AND AIR-COOLED ENGINES WHICH RESULTED IN A REPORTABLE OCCURRENCE

Over the four years 187,000 liquid-cooled and 253,000 air-cooled engines were delivered. Correcting the tables of defects to make the proportion the same gave the following results:

	Oct. 1941—Sept. 1942		Oct. 1943—Sept. 1945		Oct. 1941—Sept. 1945	
	Liquid	Air	Liquid	Air	Liquid	Air
Mechanical	15	20	22	41	37	61
Lubrication	31.5	26	28	26	59.5	52
Carburation	19.5	30	24	39	43.5	69
Ignition	6	10	3	9	9	19
Propeller	6	10	10	10	16	20
Coolant	24	0	9	0	33	0
Miscellaneous	34.5	24	14	24	48.5	48
Total	136.5	120	110	149	246.5	269
Bad maintenance and servicing	22.5	20	24	27	46.5	47
Mechanical & Lubrication	46.5	46	50	67	96.5	113

In the period 1941-1945, 0.95 defects occurred for every 1,000 liquid-cooled engines delivered.
In the period 1941-1945, 1.1 defects occurred for every 1,000 air-cooled engines delivered.

Appendix III

ANALYSIS OF CLASS I ACCIDENTS

Pilot Not Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Technical																					
Defect: Engine	5	6	0	1	12	4	2	1	3	10	2	3	4	0	9	1	2	1	1	5	36
,, : Undercarriage	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	3	0	0	4	5
,, : Brakes	0	1	0	0	1	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0	3
,, : Miscellaneous	0	1	1	0	2	0	0	1	1	2	0	1	0	0	1	0	0	0	0	0	5
Maintenance, Service, etc.	0	0	0	1	1	1	1	1	1	4	2	2	0	1	5	2	1	1	0	4	14
Airfield																					
Control faulty	0	0	0	0	0	0	2	0	0	2	1	5	0	0	6	1	0	1	0	2	10
Damage caused by others	0	0	0	2	2	0	1	0	0	1	0	1	0	0	1	1	0	0	1	2	6
Miscellaneous	1	3	0	1	5	0	0	0	0	0	1	0	0	1	2	0	0	0	0	0	7
Weather (not pilot)	1	0	1	0	2	0	2	0	0	2	0	1	0	2	3	0	1	0	0	1	8
Unclassified (not pilot)	0	1	0	0	1	0	1	0	0	1	0	1	0	1	2	2	0	0	0	2	6
Insufficient Evidence																					
Apparently airmanship	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
,, technical	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
,, weather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Others	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	8	13	2	5	28	6	9	4	5	24	6	14	5	5	30	8	8	3	2	21	103

ANALYSIS OF CLASS I ACCIDENTS

Pilot Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Taxying																					
Collision	3	3	2	0	8	3	3	1	0	7	2	0	0	3	5	1	1	0	0	2	22
Bad ground	2	0	0	0	2	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1	4
Miscellaneous	3	0	0	1	4	2	3	0	0	5	0	4	1	0	5	0	1	0	1	2	16
Cockpit Drill																					
On ground	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In flight	1	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	3
Taking Off																					
Collision	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1
Swinging	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	3
Miscellaneous	1	2	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	5
In Flight																					
Loss of control	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	3
Collision	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Landing																					
Control lost	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1
Undershooting	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1
Overshooting	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1
Swinging	0	0	1	2	3	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	4
Collision	1	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	2
Other bad landings	1	0	0	1	2	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	3
Bad Weather Flying	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	4
Other Bad Airmanship	0	2	2	0	4	0	1	0	0	1	0	2	0	0	2	0	0	0	0	0	7
TOTAL	14	9	7	5	35	6	9	1	0	16	4	9	2	4	19	2	6	1	2	11	81

ANALYSIS OF CLASS II ACCIDENTS

Other Bad Airmanship	0	2	2	0	4	0	1	0	0	1	0	2	0	0	2	0	0	0	0	0	7
TOTAL	14	9	7	5	35	6	9	1	0	16	4	9	2	4	19	2	6	1	2	11	81

ANALYSIS OF CLASS II ACCIDENTS

Pilot Not Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Technical																					
Defect: Engine	6	10	14	15	45	10	5	3	9	27	7	17	14	13	51	16	12	2	2	32	152
,, : Undercarriage	2	7	7	6	22	7	10	4	4	25	6	10	11	9	36	8	12	9	3	32	115
,, : Brakes	0	0	1	1	2	2	2	1	0	5	1	2	0	1	4	2	2	0	2	6	17
,, : Miscellaneous	4	4	3	3	14	1	3	2	2	8	2	5	4	2	13	3	4	1	0	8	43
Maintenance, Service, etc.	0	3	8	5	16	6	3	5	7	21	7	8	9	7	31	14	6	7	3	30	98
Airfield																					
Control faulty	14	7	5	11	37	3	3	5	0	11	4	5	2	0	11	3	2	3	0	8	67
Damage caused by others	1	0	1	0	2	0	6	0	0	6	0	4	3	2	9	1	2	1	0	4	21
Miscellaneous	2	2	4	1	9	2	5	4	2	13	2	0	3	2	7	3	2	0	0	5	34
Weather (not pilot)	0	1	1	0	2	1	1	0	0	2	1	0	0	0	1	1	3	1	0	5	10
Unclassified (not pilot)	2	2	1	1	6	4	1	3	0	8	3	1	0	2	6	0	3	0	1	4	24
Insufficient Evidence																					
Apparently airmanship	4	1	1	1	7	0	1	0	1	2	1	1	2	0	4	2	0	0	0	2	15
,, technical	1	1	0	0	2	0	1	1	0	2	0	1	1	1	3	1	0	0	0	1	8
,, weather	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Others	3	0	0	0	3	0	0	0	0	0	1	1	0	0	2	1	0	2	1	4	9
TOTAL	39	38	46	45	168	36	41	28	25	130	35	55	49	39	178	55	48	26	12	141	617

ANALYSIS OF CLASS II ACCIDENTS

Pilot Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Taxying																					
Collision	3	2	3	5	13	3	7	2	3	15	6	1	5	5	17	5	5	1	1	12	57
Bad ground	9	2	2	1	14	6	2	0	0	8	2	2	1	0	5	1	5	0	1	7	34
Miscellaneous	3	2	1	1	7	4	2	0	0	6	3	1	3	0	7	0	0	1	1	2	22
Cockpit Drill																					
On ground	0	0	1	2	3	3	0	1	1	5	1	1	3	0	5	0	1	1	0	2	15
In flight	3	5	2	3	13	4	3	0	1	8	0	7	1	3	11	1	3	0	0	4	36
Taking Off																					
Collision	1	1	0	0	2	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	4
Swinging	1	0	2	2	5	0	0	0	1	1	0	0	0	0	0	0	2	1	1	4	10
Miscellaneous	2	1	0	0	3	2	0	2	2	6	0	0	0	4	4	2	0	0	0	2	15
In Flight																					
Loss of control	0	0	0	1	1	0	0	0	2	2	0	1	0	1	2	0	2	0	0	2	7
Collision	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Landing																					
Control lost	4	1	2	2	9	0	1	0	1	2	0	2	1	1	4	0	2	0	1	3	18
Undershooting	1	2	0	1	4	5	0	0	1	6	0	0	0	0	0	1	2	0	0	3	13
Overshooting	10	6	1	8	25	4	4	2	1	11	2	1	0	2	5	5	0	1	2	8	49
Swinging	3	3	5	1	12	7	2	2	2	13	2	2	0	3	7	1	4	0	2	7	39
Collision	3	1	0	0	4	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	6
Other bad landings	11	9	4	5	29	6	4	3	0	13	4	1	4	1	10	6	4	0	0	10	62
Bad Weather Flying	6	12	1	4	23	1	2	1	0	4	2	3	0	0	5	3	3	1	0	7	39
Other Bad Airmanship	2	3	0	1	6	5	0	3	0	8	2	2	0	1	5	5	0	0	0	5	24
TOTAL	62	50	24	38	174	51	27	17	15	110	24	25	18	22	89	31	33	6	9	79	452

Appendix III—*continued.*

ANALYSIS OF CLASS III ACCIDENTS

Pilot Not Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Technical																					
Defect: Engine	1	1	1	1	4	2	1	0	2	5	1	2	1	0	4	2	4	1	1	8	21
,, : Undercarriage	0	1	0	0	1	0	1	1	0	2	0	0	0	0	0	1	0	0	0	1	4
,, : Brakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
,, : Miscellaneous	0	0	1	1	2	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	4
Maintenance, Service, etc.	0	0	0	0	0	1	0	1	0	2	1	1	0	2	4	0	1	0	0	1	7
Airfield																					
Control faulty	0	0	0	1	1	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	3
Damage caused by others	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	3
Miscellaneous	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Weather (not pilot)	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1	2
Unclassified (not pilot)	0	0	1	0	1	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	3
Insufficient Evidence																					
Apparently airmanship	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
,, technical	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1
,, weather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Others	1	0	0	0	1	0	1	0	0	1	0	0	0	1	1	0	0	1	0	1	4
TOTAL	2	3	4	3	12	5	6	2	3	16	2	4	1	4	11	5	7	2	1	15	54

ANALYSIS OF CLASS III ACCIDENTS

Pilot Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Taxying																					
Collision	0	0	0	1	1	1	2	1	0	4	2	1	0	0	3	0	0	0	0	0	8
Bad ground	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Miscellaneous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cockpit Drill																					
On ground	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	3
In flight	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
Taking Off																					
Collision	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Swinging	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In Flight																					
Loss of control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collision	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Landing																					
Control lost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Undershooting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Overshooting	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	1	1	0	2	4
Collision	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Other bad landings	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Bad Weather Flying	1	1	0	0	2	1	0	1	0	2	1	1	0	0	2	0	0	0	0	0	6
Other Bad Airmanship	0	0	0	0	0	2	0	0	1	3	0	0	0	0	0	1	1	0	0	2	5
TOTAL	2	4	2	1	9	4	6	2	1	13	3	2	0	0	5	2	2	2	0	6	33

ANALYSIS OF CLASS IV ACCIDENTS

Pilot Not Responsible

Other Bad Airmanship	0	0	0	0	0	2	0	0	1	3	0	0	0	0	0	1	1	0	0	2	5
TOTAL	2	4	2	1	9	4	6	2	1	13	3	2	0	0	5	2	2	2	0	6	33

ANALYSIS OF CLASS IV ACCIDENTS

Pilot Not Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Technical																					
Defect: Engine	4	7	15	8	34	13	10	6	11	40	10	7	7	9	33	6	5	7	0	18	125
,, : Undercarriage	4	3	2	6	15	4	9	6	3	22	3	9	6	4	22	4	6	0	2	12	71
,, : Brakes	0	2	0	1	3	1	1	1	0	3	0	0	0	0	0	0	1	0	0	1	7
,, : Miscellaneous	0	1	0	2	3	0	2	1	4	7	0	2	4	3	9	1	2	0	0	3	22
Maintenance, Service, etc.	0	1	2	1	4	5	2	8	9	24	4	3	0	5	12	1	0	1	1	3	43
Airfield																					
Control faulty	2	0	3	0	5	0	3	5	0	8	4	2	1	1	8	1	0	2	0	3	24
Damage caused by others	1	0	0	1	2	0	2	1	0	3	0	1	0	0	1	0	1	1	0	2	8
Miscellaneous	0	3	0	0	3	1	1	2	0	4	3	1	2	2	8	2	3	0	0	5	20
Weather (not pilot)	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	3
Unclassified (not pilot)	1	0	1	0	2	2	0	0	0	2	1	2	0	0	3	3	1	0	0	4	11
Insufficient Evidence																					
Apparently airmanship	3	0	1	2	6	1	0	0	0	1	1	1	0	0	2	0	0	0	0	0	9
,, technical	0	0	0	0	0	2	1	0	2	5	1	1	1	2	5	0	0	1	0	1	11
,, weather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Others	2	2	0	1	5	0	1	0	0	1	1	0	1	0	2	0	0	1	0	1	9
TOTAL	18	20	24	22	84	29	32	30	29	120	28	27	22	26	105	18	20	13	3	54	363

ANALYSIS OF CLASS IV ACCIDENTS

Pilot Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Taxying																					
Collision	3	0	0	3	6	1	3	1	0	5	5	6	0	0	11	1	1	0	0	2	24
Bad ground	0	0	0	0	0	1	1	0	0	2	2	1	0	0	3	0	0	0	0	0	5
Miscellaneous	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	1	0	1	4
Cockpit Drill																					
On ground	1	0	0	1	2	0	2	0	2	4	0	3	0	0	3	0	1	1	0	2	11
In flight	0	0	0	2	2	1	0	2	1	4	1	1	1	0	3	1	2	0	1	4	13
Taking Off																					
Collision	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Swinging	2	0	1	1	4	2	2	1	4	9	1	3	1	1	6	1	0	2	0	3	22
Miscellaneous	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	3
In Flight																					
Loss of control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collision	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Landing																					
Control lost	2	1	0	0	3	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	4
Undershooting	0	2	0	0	2	2	0	1	0	3	0	0	0	0	0	0	0	0	0	0	5
Overshooting	1	0	0	0	1	0	0	0	1	1	0	0	0	1	1	3	2	0	1	6	9
Swinging	0	1	4	1	6	0	3	0	0	3	1	2	0	1	4	1	2	1	0	4	17
Collision	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Other bad landings	1	0	1	1	3	0	0	0	0	0	3	1	1	4	9	1	2	1	1	5	17
Bad Weather Flying	2	0	0	1	3	0	0	0	0	0	3	2	1	0	6	0	0	0	0	0	9
Other Bad Airmanship	0	1	0	0	1	2	2	1	0	5	1	1	1	0	3	1	1	0	0	2	11
TOTAL	14	5	6	11	36	10	13	6	9	38	18	21	5	7	51	9	11	6	5	31	156

Appendix III—*continued.*

ANALYSIS OF CLASS V ACCIDENTS

Pilot Not Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Technical																					
Defect: Engine	0	0	0	0	0	3	1	0	3	7	5	3	0	4	12	9	6	7	1	23	42
,, : Undercarriage	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	1	0	0	3	4
,, : Brakes	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1
,, : Miscellaneous	0	1	0	1	2	0	0	1	0	1	0	1	0	1	2	0	0	1	0	1	6
Maintenance, Service, etc.	0	0	1	0	1	1	3	0	2	6	0	2	2	1	5	0	1	1	0	2	14
Airfield																					
Control faulty	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Damage caused by others	0	0	1	0	1	1	0	0	0	1	0	1	0	0	1	1	0	0	0	1	4
Miscellaneous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weather (not pilot)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
Unclassified (not pilot)	0	0	0	0	0	1	1	1	0	3	0	2	1	0	3	2	1	1	0	4	10
Insufficient Evidence																					
Apparently airmanship	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
,, technical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
,, weather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Others	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2
TOTAL	1	1	2	2	6	7	5	2	5	19	5	10	4	7	26	15	9	10	1	35	86

ANALYSIS OF CLASS V ACCIDENTS

Pilot Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Taxying																					
Collision	0	0	0	0	0	1	0	0	0	1	0	1	1	1	3	0	0	0	0	0	4
Bad ground	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cockpit Drill																					
On ground	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In flight	0	0	2	0	2	0	0	0	0	0	0	0	1	0	1	2	0	0	0	2	5
Taking Off																					
Collision	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Swinging	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1
Miscellaneous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In Flight																					
Loss of control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collision	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Landing																					
Control lost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Undershooting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Overshooting	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
Swinging	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collision	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1
Other bad landings	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Bad Weather Flying	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1
Other Bad Airmanship	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1
TOTAL	0	0	3	0	3	2	0	1	0	3	1	2	2	3	8	2	0	0	0	2	16

ANALYSIS OF CLASSES I—V ACCIDENTS

Pilot Not Responsible

Bad Weather Flying	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1
Other Bad Airmanship	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1
TOTAL	0	0	3	0	3	2	0	1	0	3	1	2	2	3	8	2	0	0	0	2	16

ANALYSIS OF CLASSES I—V ACCIDENTS

Pilot Not Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Technical																					
Defect: Engine	16	24	30	25	95	32	19	10	28	89	25	32	26	26	109	34	29	18	5	86	379
,, : Undercarriage	7	11	9	12	39	11	20	11	7	49	9	19	18	13	59	16	22	9	5	52	199
,, : Brakes	0	3	1	2	6	3	3	3	0	9	1	3	1	1	6	3	3	0	2	8	29
,, : Miscellaneous	4	7	5	7	23	1	5	5	8	19	2	9	8	6	25	5	6	2	0	13	80
Maintenance, Service, etc.	0	4	11	7	22	14	9	15	19	57	14	16	11	16	57	17	9	10	4	40	176
Airfield																					
Control faulty	16	7	8	12	43	5	9	10	0	24	9	12	3	1	25	5	2	6	0	13	105
Damage caused by others	2	1	2	3	8	2	9	1	0	12	0	7	3	2	12	3	4	2	1	10	42
Miscellaneous	3	8	5	2	18	3	6	6	2	17	6	1	5	5	17	5	5	0	0	10	62
Weather (not pilot)	2	2	2	0	6	1	4	0	0	5	1	1	0	2	4	2	6	1	0	9	24
Unclassified (not pilot)	3	3	3	1	10	7	3	4	0	14	4	7	1	4	16	7	5	1	1	14	54
Insufficient Evidence																					
Apparently airmanship	7	1	2	4	14	1	1	0	1	3	2	2	2	0	6	2	1	0	0	3	26
,, technical	1	2	0	0	3	3	3	1	2	9	1	2	2	3	8	1	0	1	0	2	22
,, weather	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Others	7	2	0	1	10	0	2	0	0	2	2	1	1	2	6	1	0	4	1	6	24
TOTAL	68	75	78	77	298	83	93	66	67	309	76	112	81	81	350	101	92	54	19	266	1223

ANALYSIS OF CLASSES I—V ACCIDENTS

Pilot Responsible

	1941-1942					1942-1943					1943-1944					1944-1945					Grand
	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	4	1	2	3	Tl.	Total
Taxying																					
Collision	9	5	5	9	28	9	15	5	3	32	15	9	6	9	39	7	7	1	1	16	115
Bad ground	11	2	2	1	16	7	5	0	0	12	4	3	1	0	8	1	6	0	1	8	44
Miscellaneous	6	2	1	3	12	7	5	0	0	12	3	6	4	0	13	0	1	2	2	5	42
Cockpit Drill																					
On ground	1	1	1	3	6	3	3	1	3	10	1	4	3	0	8	1	2	2	0	5	29
In flight	4	5	6	5	20	5	3	2	2	12	1	8	3	3	15	4	6	1	1	12	59
Taking Off																					
Collision	1	1	0	0	2	0	0	1	0	1	0	1	1	0	2	0	0	0	0	0	5
Swinging	3	0	4	3	10	2	2	1	5	10	1	4	1	2	8	1	3	3	1	8	36
Miscellaneous	4	3	0	1	8	2	0	2	3	7	0	0	0	4	4	2	0	1	1	4	23
In Flight																					
Loss of control	2	0	0	1	3	0	0	0	2	2	0	1	0	1	2	1	2	0	0	3	10
Collision	0	0	0	1	1	2	1	0	0	3	0	0	0	0	0	0	0	0	0	0	4
Landing																					
Control lost	6	2	2	2	12	0	1	0	1	2	1	3	1	1	6	0	2	0	1	3	23
Undershooting	1	4	0	1	6	7	0	1	1	9	0	0	0	1	1	1	2	0	0	3	19
Overshooting	11	6	3	8	28	4	5	3	2	14	2	2	0	3	7	8	3	2	3	16	65
Swinging	3	4	10	4	21	7	6	2	2	17	3	4	0	4	11	2	6	1	2	11	60
Collision	6	1	0	0	7	0	0	0	0	0	1	0	0	2	3	1	0	0	1	2	12
Other bad landings	13	11	5	7	36	7	4	3	0	14	8	2	5	5	20	7	6	1	1	15	85
Bad Weather Flying	9	15	1	5	30	2	2	2	0	6	6	7	1	0	14	3	4	1	1	9	59
Other Bad Airmanship	2	6	2	1	11	9	3	4	1	17	4	5	1	1	11	7	2	0	0	9	48
TOTAL	92	68	42	55	257	73	55	27	25	180	50	59	27	36	172	46	52	15	16	129	738

CORRESPONDENCE

THE GAS TURBINE PAPERS AND DISCUSSION

To The Editor:— 14*th April*, 1946.

No one has reason to complain of Dr. Hooker's enthusiasm for the simple jet engine as long as it does not lead to a false supposition that the problems of its application to civil aircraft have already been solved.

Without doubt the time is ripe for building experimental civil aircraft; for example, a high speed mailplane with jet engines. One hopes that several projects of this kind will be sponsored in the near future because it is clearly the only way to assess and develop the safety, economy and reliability of the engine and its appropriate aircraft.

It appears as though the pure jet and the propeller turbine will require a period of some years before we see them operating as regularly and universally as the piston engine is to-day, but their popularity will grow as their problems are solved. These problems fall roughly under four headings.

1. Economy of first cost and maintenance have fallen short of expectations. A good deal of development and rationalisation is required by designers and metallurgists to bring down the cost of blades, discs and combustion chambers. The engine auxiliaries are, as yet, a bit reminiscent of piston engine components. The design of starting systems and fuel systems and controls does not compare yet with the gas turbine itself in regard to basic simplicity, lightness and compactness. In developing the design of engine and auxiliaries alike, attention must be devoted to the right balance between lightness and good serviceability.

2. The low idling torque and the inertia of the rotors of turbine engines and their different handling characteristics, at first, will cause a certain amount of apprehension to all but a few highly trained military and test pilots. The method of control used on piston engines does not necessarily suggest the best solution for the gas turbine and our present technique of handling engines in the air will most likely need to be revised.

3. Operators are being pressed to contend with a large number of new conditions at one and the same time and, so far, without much evidence upon which to judge their effects. Naturally they wonder how far the experience gained with the gas turbine under service conditions is going to apply to civil use. We are setting out to achieve overhaul periods similar to those of the best reciprocating engines, but the operator has not yet been convinced of the certainty or consistency of the overhaul period and has little information upon which to base the size and cost of terminal and intermediate service stations, or the nature and extent of spares and equipment.

4. It appears as though the gas turbine engine driving a propeller will provide the motive power for short ranges where the distance involved and the weight of a pressure cabin argue against flying at high altitudes. But in order to take full advantage of the pure jet engine for medium and long ranges, it will be necessary to develop the high altitude, air-conditioned cabin. There is a danger of under-estimating the difficulty of constructing such a cabin which would be acceptable for general use and the choice still lies open at this date between the pure jet and some form of propeller turbine with a heat exchanger or perhaps the compound engine. Both of these would permit long distances to be flown at lower altitudes where the pressure cabin problem would be less acute. This is the justification for proceeding with the development of heat exchangers and with an engine such as has been

proposed by Dr. Ricardo. One feels, however, that the ultimate answer will not be altogether fairly judged on economic factors alone and after all the factual costs have been assessed we shall be prepared to pay a little more for smoother, quieter and quicker travel and for the mere satisfaction of being rid of the propeller.

D. R. AMOR, Associate Fellow (Roy Fedden, Ltd.)

To The Editor:— *7th May*, 1946.

After reading the most interesting proposals put forward by Mr. Ricardo in his recent paper on " Turbine Compounding of the Piston Aero Engine " one is left with the feeling that the admirable brevity and conciseness with which they have been presented might make the project too attractive to minds less familiar with thermodynamics than the author's.

At first sight it would appear that two blacks are being made into a white, for Mr. Ricardo has purported to show how, by compounding with an inefficient and uneconomical turbine engine an inefficient and uneconomical two-stroke compression-ignition engine, a power unit of transcendental overall economy can be obtained.

Various practical difficulties which militate against this, however, are likely to bring it down to more mundane levels.

In the first case, it is not so generally appreciated as might be supposed that the turbine engine is internally cooled, whereas the piston engine, neglecting for the moment those types which make abundant use of the lubricating oil, is externally cooled. In this respect the airscrew can be compared with the compressor of the turbine engine in that part of its function is to deliver air for cooling the engine. Granted that the two-stroke engine will receive a large measure of internal cooling from the excess air which is supplied, nevertheless, the problem of cooling the cylinder of a Mercury-sized engine producing 4,000 h.p. will be one of considerable difficulty.

Moreover, in the estimate of overall weight it is important to take full account of the inter-cylinder baffling and exhaust arrangments necessary to achieve satisfactory cooling. The weight of cowling, baffling and exhaust system for an air-cooled engine is of the order of 17 per cent. to 20 per cent. of the dry weight of the engine, so that an appreciable amendment needs to be applied to the weight estimates.

Incidentally, when comparisons are made of the fuel economy and weight of piston and turbine engines, the piston engine should be debited with its cooling drag horse power and the weight of these items, the equivalents of which are already built integrally into the turbine engine.

One last point—advantage has already been taken by the R.A.F. of the reduced ground maintenance staff needed for turbine engines. The re-introduction of a piston engine, simple though it may be, but penalised by the need for more involved exhaust gas piping (never a joy), and requiring probably more complicated gearing, would inevitably require larger ground crews than ever before.

While compounding will always have its attractions and its adherents, success in the aviation field has so often come to the man who has limited his objective and who has concentrated his efforts on a narrow front, that there are strong grounds for assuming that the best results will be achieved by more orthodox power units of greater simplicity, and very probably of the same ultimate overall efficiency as the compounded unit.

FRANK NIXON, B.Sc., M.S.A.E., Fellow (Rolls-Royce, Ltd.)

REVIEW

World Power and Atomic Energy.

H. E. Wimperis, C.B., C.B.E., F.R.Ae.S Constable & Co., London, 1946. 6/- net.

Mr. Wimperis, a former President of the Royal Aeronautical Society, and from 1925-37 Director of Scientific Research at the Air Ministry, speaks with authority and vision on air matters. It was due to his vision, indeed, that the Royal Air Force entered the second World War better able to face the power of th Luftwaffe than any other air force in the World.

What he has to say on atomic energy and the atomic bomb, therefore, deserves careful attention. To quote from his preface: " With the facts fairly presented, as has been my endeavour, readers have the material on which to base their own judgement, and their actions, as to the policy which our Government, with others, should follow. We face a great moral issue, a challenge to all that is best in us."

On page 80 he expands on the theme. " The path before us may call for humility of soul; for a cleansing of hearts, everywhere, from pride, vain glory and hypocrisy—and, not least—from all unworthy national ambitions."

It may take an atomic war to do the cleansing, for it is clearly evident that the past six years of war have taught most nations little of that " humility of soul " or that " cleansing from all unworthy national ambitions." They are, indeed, jockeying for strategic bases, with fear in their eyes, with national arrogance in their speech, and little humility in their hearts.

The situation calls for such a great spiritual change throughout the world that the possibility of that change taking place in our time is small. It can only be in time by a constant and as great, and as world-wide, a call from the spiritual leaders as is now being given to the atomic bomb and the uses of atomic energy. The emphasis should be on the spiritual change and what it will mean, on the means of salvation of the body and soul and not on the means of their destruction.

There is little sign of that trumpet call. A few voices are raised here and there, but the sound of the voices of the world in unison can only be loud enough to drown that of the atomic bomb.

Mr. Wimperis gives in an Appendix the three-power statement on atomic energy, issued by the President of the United States, the Prime Minister of the United Kingdom, and the Prime Minister of Canada.

It is a statement purely of what concrete action should be taken to control the atom against its use in war or for its use for the benefit of mankind.

It is not that message to the world which will move it profoundly, must move it indeed, if man is not to regress two thousand years.

It is to be hoped that Mr. Wimperis' book will be widely read, for it states the problem clearly and shortly for all men of good heart to read, for all to know that in their hearts and in their hearts alone, lies the answer to the question " Whither mankind?"

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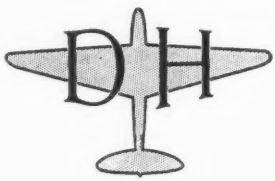

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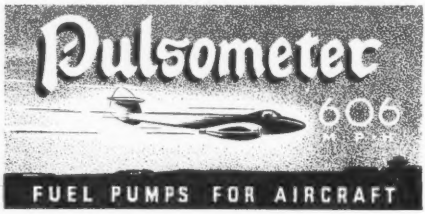

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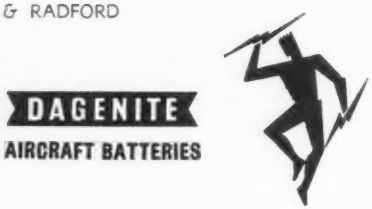

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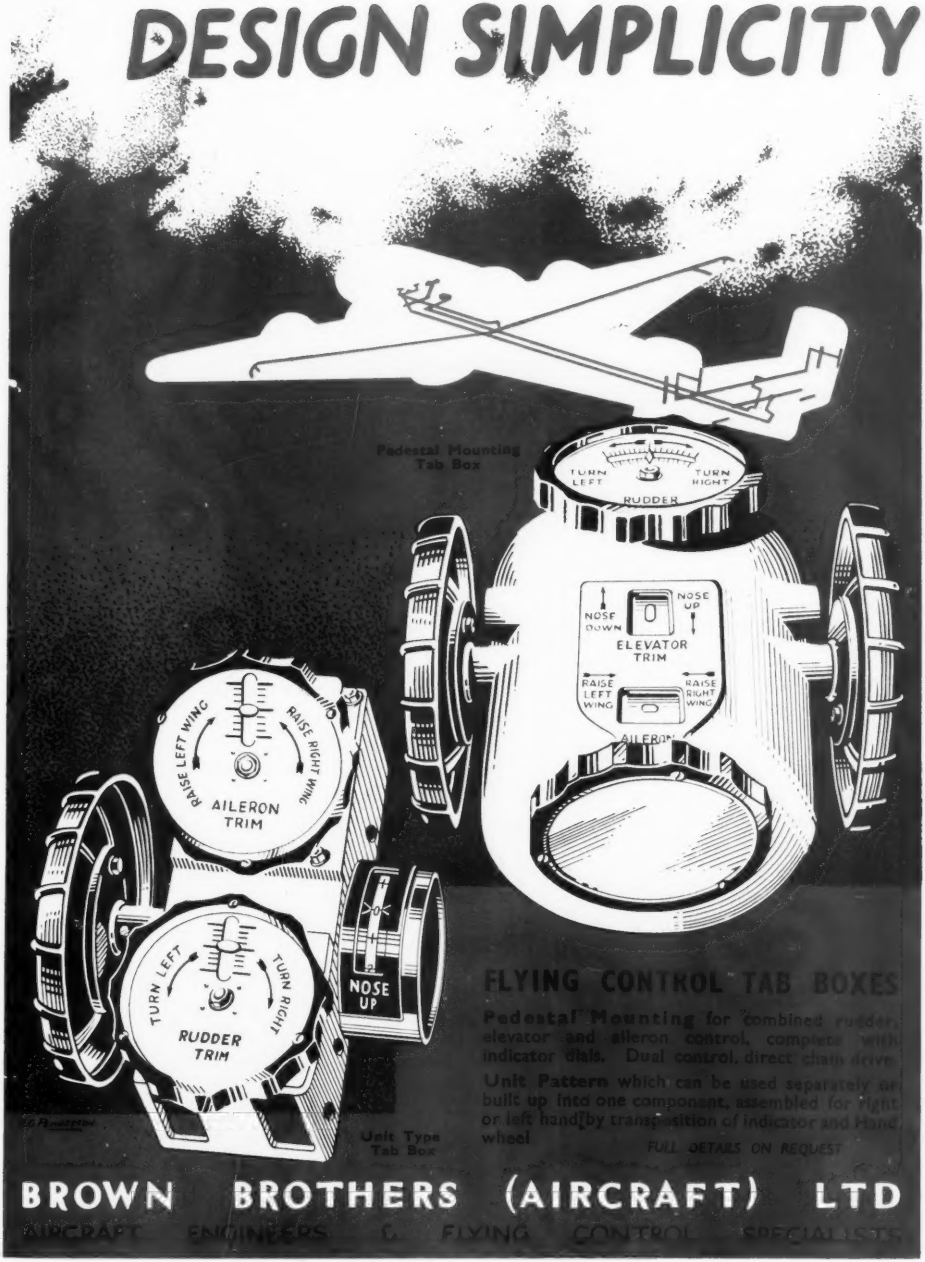

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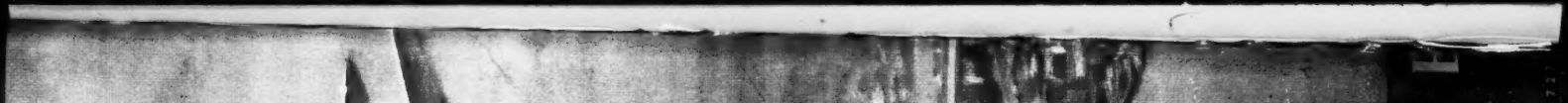

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THE ROYAL AERONAUTICAL SOCIETY

4, HAMILTON PLACE, PICCADILLY, LONDON, W.1

JANUARY NOTICES 1946

JOURNAL PREMIUM AWARDS

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the *Journal* and the Council hope that members (or non-members) will contribute papers on their own special subjects.

The January Journal

The January Journal is a special number commemorating the eightieth anniversary of the Society. A copy will be sent to each member of the Society.

Contents of January Journal

The President's Address to Members.

A Chronology of the Society from 1866 to 1946.

The First British Commonwealth and Empire Lecture—"Australia in Air Transport," by W. Hudson Fysh, M.C.

Journal

The January Journal begins the 50th volume. The earlier printed records of the Society were Annual Reports containing accounts of the year's activities and lectures.

Eightieth Anniversary

January 12th, 1946, is the eightieth anniversary of the founding of the Society. It is being celebrated by a dinner at the Guildhall on Friday, January 11th, 1946, a Reception by the President and Council at the Society's Headquarters on Saturday, January 12th, 1946, from 3 to 6.30 p.m., and by local celebrations of the Branches.

History of the Society

A history of the Society for the past eighty years has been prepared and is available to all members, price five shillings (5/3 post paid). It is hoped that members will obtain a copy of the souvenir history of the oldest Aeronautical Society in the world. The edition is strictly limited and it will not be possible to have it reprinted, so an early application is necessary. The Souvenir is fully illustrated and gives an account of the pioneer work of members of the Society, and the steady growth in its power and prestige.

Election of Council

Attention is drawn to the following Rules for election to Council. Nominations should be received by March 1st, 1946. Nomination forms may be obtained from the Secretary. Nomination forms may be signed by any members of the Society excepting Honorary Fellows, Graduates and Students.

Rule 71.—One-half of the Council (excluding the President and the immediate Past-President if a Member of Council) shall retire annually. The members who shall retire shall be those longest in office, except as provided in Rule 77. Retiring Members of Council who have served for two terms in succession (four years) shall not be eligible for re-election until the next annual election, when they will be eligible.

Rule 72.—The composition of the Council shall be as follows:—

(*a*) Not less than sixteen shall be elected from the technical or scientific grades of the R.Ae.S.—that is to say, from among the Fellows, Associate Fellows and Associates.

(*b*) Of these sixteen, four at least shall be Fellows.

Rule 73.—Nominations of candidates for election to the Council must be received by the Secretary not less than twenty-one days before the Annual General Meeting, with an intimation in writing by the candidates that they are willing to serve. Nominations must be signed by one supporter and two seconders, who must be each entitled to vote in the R.Ae.S.

Fellowship

Members are reminded that under the Rules election to Fellowship is made annually and that all nominations must be received by March 1st at the latest on Form A obtainable from the Secretary.

Lecture Programme

The following are the forthcoming lectures. Members are admitted without tickets, but non-members must obtain tickets through a member.

The Lectures will be held at 6 p.m. in the Lecture Hall of the Institution of Civil Engineers, Great George Street, S.W.1 (by permission of the Council of the Institution). In each case tea will be served at 5.30 p.m.

February 13th—Selection of Engineering Personnel for the Aircraft Industry, by Mr. F. Holliday, B.Sc., F.P.S., A.F.R.Ae.S.

February 28th—The Application of Radio to Civil Aviation, by Sir Robert Watson-Watt, C.B., LL.D., F.R.S., F.R.Ae.S.

March 13th—DISCUSSION ON THE GAS TURBINE.

A full day discussion will be held at which the following papers will be read:—

MORNING SESSION.

11 a.m. The Application of the Gas Turbine to Aircraft Propulsion, by Dr. S. G. Hooker.

12 noon. Turbine-Compounding of the Piston Aero Engine, by Dr. H. Ricardo, F.R.S., F.R.Ae.S.

1-2.30 p.m. Luncheon Interval. Members and visitors to make their own arrangements for lunch.

AFTERNOON SESSION.

2.30 p.m. The Application of the Gas Turbine in its Forms to the Field of Commercial Aviation, by Mr. R. M. Clarkson, F.R.Ae.S.

3.30 p.m. The Application of the Gas Turbine in its Forms to the Field of Military Aviation, by Mr. W. G. Carter, F.R.Ae.S.

4.30-5 p.m. Tea Interval (tea provided).

EVENING SESSION.

5-6.30 p.m. General Discussion and Summing-up by the Chairman.

March 28th—The Electrical Measurement of Strain, by Dr. S. C. Redshaw, F.R.Ae.S.

April 10th—The Silencing of Aircraft, by Mr. Fleming, M.A.

April 25th—Modern Aeronautical Materials by Dr. L. Aitcheson, F.R.Ae.S.

May 30th—The Thirty-Fourth Wilbur Wright Lecture will be read by Mr. E. F. Relf, C.B.E., F.R.S., F.R.Ae.S.

Graduates' and Students' Section

January 23rd—Low Drag Aerofoils, by Dr. L. G. Whitehead, Ph.D., A.F.R.Ae.S., Lecturer in the Aeronautical Engineering Department, Queen Mary College.

February 7th—Technical Activities—A Discussion led by Dr. D. M. A. Leggett, A.F.R.Ae.S., Technical Secretary of the Society.

February 26th—Tailless Aircraft, by Mr. G. H. Lee, A.F.R.Ae.S., of Handley Page, Ltd.

March 20th—Film Show. Radar.

April 16th—Flight Refuelling, by Sir Alan Cobham, K.B.E., A.F.C., Hon. F.R.Ae.S.

May 2nd—Transport Aircraft, by Mr. Frank Radcliffe, F.R.Ae.S., of Handley Page, Ltd.

All Lectures will be read in the Library of the Society, 4, Hamilton Place, W.1, at 7.30 p.m.

Visitors to these lectures are welcomed.

Branch Lectures

BELFAST BRANCH

February 12th—Radio Aids to Navigation, by Mr. S. N. Jackson.

March 12th—Model Tank Testing of Flying-Boat Hulls and Floats, by Mr. L. Smith, A.F.R.Ae.S.

BIRMINGHAM BRANCH

January 16th—Discussion on "The Future of Air Transport and the Extent to which it may Supplement or Supersede Surface Transport," led by Sir Frederick Handley Page, F.R.Ae.S. (President of the Society).

February 5th—Production of Light Alloys for Use in Aircraft, by Mr. J. R. Handforth, M.Sc.

March 6th—Flying-Boats—Their Development and Possibilities, by Mr. A. Gouge, F.R.Ae.S. (Past-President of the Society).

Lectures will be at 7 p.m. in the Birmingham Chamber of Commerce, 95, New Street, Birmingham.

BRISTOL BRANCH

January 29th—Brains Trust and Debate. Question Master, Captain J. Laurence Pritchard, Hon.F.R.Ae.S.

February 1st—Celebration Dance at the Victoria Rooms at 8.30 p.m.

February 19th—Reading of Prize-winning Papers by Junior Members.

March 12th—Industry's Part in Aeronautical Research, by Mr. W. S. Farren, C.B., F.R.S., F.R.Ae.S.

April 2nd—Research in Aeronautics, by Sir Benny Lockspeiser, F.R.Ae.S.

All meetings will be held in the Conference Room, Bristol Aeroplane Company, Ltd., Filton House, at 6.30 p.m.

COVENTRY BRANCH

January 18th—Exhibition Evening in the Council Staff Canteen, Old Gulson Library, at 7 p.m.

LEICESTER BRANCH

February 2nd—Gliding in Germany during and since the War, by Senior Commander P. Wills, A.T.A.

February 20th—Low-Drag Aerofoils, by Dr. L. G. Whitehead.

March 6th—Airscrews, by Mr. J. A. C. Williams, A.F.R.Ae.S.

April 10th—Post-War Transport Aircraft Design, by Mr. F. Radcliffe, F.R.Ae.S.

Lectures will be held in Room 45 of Leicester Technical College at 7.30 p.m.

LUTON BRANCH

February 6th—Some Aspects of Aircraft Design, by Mr. D. L. Brown, A.F.R.Ae.S., of Miles Aircraft.

GLASGOW BRANCH

January 17th—The History of the Aircraft Industry in Scotland, by Mr. C. A. Oakley, B.Sc., in the Royal Technical College, Glasgow.

MEDWAY BRANCH

February 11th—Production Organization, by Mr. D. E. Wiseman, in the Mathematical School Hall, Rochester, at 6 p.m.

ISLE OF WIGHT BRANCH

January 15th—German War-time Aircraft Design, by Mr. H. Knowler, F.R.Ae.S., Saunders Roe Sports and Social Club, East Cowes, at 6.45 p.m.

READING BRANCH

January 16th—Compressibility Effects, by Dr. W. F. Hilton.

Annual Subscriptions of Members

Members are reminded that their 1946 subscriptions became due on January 1st, 1946.

The following will be the rates for 1946 therefore:—

	Home. £ s. d.	Abroad. £ s. d.
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Students	1 1 0	1 1 0
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* £1 1s. 0d. without Journal.

Binding of Journals

Owing to increased costs, the prices of binding of Journals will be as follows:—

1945 Volume	10s. 0d.
Previous Volumes	12s. 0d.

Journals should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the office of the Society.

Election of Members

The following members were recently elected:—

Associate Fellows

George Ernest Airey, Bryan Cyril Alford, Cyril George Buxton, Richard Dyrgalla (from Associate), Charles Denis Hatton, Shukry Kamel Ibrahim (Ex-Student), Charles William Labette, Philip Hector Lawrence, John Harold Linwood, George Hinson Rider (from Student), Henry John Swift, Jacques Valensi.

Companions

Derek Guy Harcourt Higgins, Joseph Mauric Paturau.

Associates

John Stace Aitken, Shankerlal Amin, Frank Oxley Baines (from Student), Serge Charles Bentley, Ralph Brown, Arthur Henry Bulpitt, Stanley Robertson Calder, Ernest Laurence Daniel, Marshall Osborne Day, N. S. De Haas, Lewis William Fielder, Horace Goldthorpe, Alexander Myles Jardine (from Student), Melville Harry Scott Innes-Jones, Thomas Hendy Marsden, Frank Osmond Martin, R. Narasimhan, Noel Henry Nash (Ex-Student), Charles William Sheppard, Thomas William Jacques Temple, Ernest Percival Vickery, Albert Edward Williams.

Graduates

Gilbert Seymour Cranwell, Basil St. John Emery, Robert James Holland, Abdel Hamid Mahmoud, John Eric Rhodes (from Student), Marion Barbara Thorn.

Students

David Dudley Annenberg, Bernard Cecil Banham, Austin Barltrop, Kenneth Ivor Walter Bouch, Earle Francis William Brown, Peter Gardner Browne, Alan George Hobbs, Norman Leslie Edwin King, Philip George Lockington, Thomas Leo Shelton, Leonard Stockdale, Leslie Young.

Additions to the Library

Pamphlets in italics with location reference following in brackets. Books marked * or ** may not be taken out on loan.

AA.—*Aeronautical Research Committee: Reports and Memoranda.*

No. 1978.—*Stream Expansion with Discontinuity in Velocity on the Boundary. N. J. S. Hughes. H.M. Stationery Office.* 1944. 2/-.

No. 1979.—*Spring Tab Controls. W. S. Brown. H.M. Stationery Office.* 1941. 3/-.

No. 1928.—*The Vibration of an Aircraft with Specific Reference to the Wings. J. Morris and I. T. Minhinnick. H.M. Stationery Office.* 1940. 7/-.

NOTICES

No. 1937.—*Flight and Model Tests of the "Hawoon" with Wings 33 per cent. Thick at the Root.* 1939. 7/-.

No. 1908.—*On the Stressing of Polygonal Tubes with Particular Reference to the Torsion of Tapered Tubes of Trapezoid Section. H. L. Cox. H.M. Stationery Office.* 1942. 10/-.

No. 1968.—*Some Approximate Representations for the Airload Coefficients of Two-Dimensional Vortex Sheet Theory. J. Williams. H.M. Stationery Office.* 1945. 4/-.

No. 1970.—*Note on the Lateral Stability of the C.30 Autogiro Seaplane. J. A. Beavan. H.M. Stationery Office.* 1945. 2/6.

No. 1960.—*A Comparison of Hinge Moments of Flaps on N.A.C.A.* 4412 *as Determined by Theory and Experiment. J. H. Preston and T. W. Brown. H.M. Stationery Office.* 1941. 2/-.

No. 1961.—*Flight Tests of the Effect of Flaps, Slots and Wing Taper on Lateral Stability and Control. R. H. Francis. H.M. Stationery Office.* 1937. 3/6.

B.e.43.—How to Organise a Club for Aeromodellers. Association of British Aeromodellers. 1944. 1/-.

D.c.103.—*Airport Management. Department of Commerce, U.S.A. U.S. Government Printing Office.* 1944. 8d. PD4.8.

EE.c.77.—An Introduction to Heat Engines. E. A. Allcut. University of Canada. 1945.

G.e.D.26.—Newnes Plastics Manual. F. J. Camm. Published by George Newnes. 1945. 17/6.

K.c.23.—Rockets. Willy Ley. The Viking Press, U.S.A. 1945. 22/6.

L.a.54.—Airplane Performance and Operation. R. Dixon Speas. McGraw-Hill Book Co. 1943. 12/6.

L.d.109.—Basic Air Navigation. Elbert F. Blackburn. McGraw-Hill Book Co. 1944. 24/-.

N.c.15.—Elementary Qualitative Analysis. Bruce E. Hartsuch. John Wiley & Sons, U.S.A. 1943. 12/6.

S.e.113.—Bombing Vindicated. J. M. Spaight. Geoffrey Bles. 1944. 6/-.

S.e.114.—Air Strategy. Norman Macmillan. Hutchinson. (1941.) 2/6.

*X.c.B.25.—Glossary of Aeronautical Terms. British Standards Institution. 1940. 7/6.

*X.e.56.—Aeronautical Engineering Catalogue. Institute of the Aeronautical Sciences. 1945.

J. LAURENCE PRITCHARD,
Secretary.

Made and Printed in Great Britain by the Lewes Press, Lewes, Sussex.

TECHNOLOGY DEPT.

THE ROYAL AERONAUTICAL SOCIETY

4, HAMILTON PLACE, PICCADILLY, LONDON, W.1

FEBRUARY NOTICES 1946

JOURNAL PREMIUM AWARDS

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the *Journal* and the Council hope that members (or non-members) will contribute papers on their own special subjects.

Contents of February Journal

Frontispiece—View of the Dinner at Guildhall on the 11th January, 1946.

The King—Photograph and Message.

Messages of greetings and good wishes received by the Society on its eightieth anniversary.

An account of the eightieth anniversary celebrations of the Society.

New Year Honours.

" Flutter of Propeller Blades," by J. V. Inglesby, M.A., D.I.C., A.F.R.Ae.S.

A copy of the description of the eightieth anniversary celebrations, which is illustrated with photographs of the dinner at Guildhall, will be sent to members of the Society who do not receive the Journal.

International Congress for Applied Mechanics

The Sixth International Congress for Applied Mechanics will be held in Paris, at the Sorbonne, from the 22nd to the 29th September, 1946. The President of the French Organisation Committee is M. Henri Villat and the Secretary-General is M. Maurice Roy.

The Congress will be divided into the following Sections:—

1. Structures; Elasticity; Plasticity.
2. Hydro and Aerodynamics; Hydraulics.
3. Solid Dynamics; Vibration and Sound; Friction and Lubrication.
4. Thermodynamics; Heat Transfer; Combustion; Fundamentals of Nuclear Energy.

In addition a number of General Lectures will be given on subjects of current interest.

Those wishing to become members of the Congress should inform the Secretary-General of their intention to attend as soon as possible and should also indicate whether they wish to present a paper. Either the manuscript of the paper (not exceeding 5,000 words), or a summary of not more than 300 words, must reach the Secretary-General by the 31st July, 1946.

The subscription fee for members of the Congress is 300 francs. The Organisation Committee recommends that payment should be made on the opening day of the Congress. Adequate facilities will be provided for members during their stay in Paris.

Communications should be addressed to the Secretary-General, Sixth International Congress for Applied Mechanics, Institut Henri-Poincaré, 11 rue Pierre-Curie, Paris (V^e).

Professor Jacque Valensi is the representative in London of the French Organisation Committee at 1, Carlton Gardens, S.W.1.

For the information of members of the Society who wish to attend the Congress, British subjects are now allowed to take £100 a year out of the country for travelling purposes. Only 2,000 francs may be taken, but more may be sent through a bank to Paris. The new rate of exchange is 480 francs to the £.

An Air Mail Collection

At the suggestion of many members, a collection of First Day air mail covers, general air mail covers and air mail stamps is being formed by the Society. This collection will be available for inspection by members at the headquarters of the Society as soon as it has reached a suitable size.

The Society would be grateful if any members who have covers or stamps they do not require would present them to the Society to assist in the formation of this collection.

Photographs of the Dinner at Guildhall

Members who attended the above function are invited to inspect photographs in the Society's offices taken during the course of the evening. Copies will be supplied on application to the Secretary, at 2s. 6d.

Acknowledgements

The Council acknowledge with thanks the gift of books for the Library from the following members: Mr. G. B. Burnside (Associate Fellow), Captain A. N. Barrett (Associate Fellow), and Mr. M. W. Wood (Associate Fellow), and the gift of photographs from: Mr. J. W. Truran (Associate), English Electric Company (Stafford), and Short Brothers, Ltd. The Council also wish to acknowledge the gift of Journals of the Society from the following members: Mr. J. D. Campbell (Associate Fellow), Mrs. Walker Sinclair (Companion), and Mr. R. McKinnon Wood (Fellow).

Election of Council

Attention is drawn to the following Rules for election to Council. Nominations should be received by March 1st, 1946. Nomination forms may be obtained from the Secretary. Nomination forms may be signed by any members of the Society excepting Honorary Fellows, Graduates and Students.

Rule 71.—One-half of the Council (excluding the President and the immediate Past-President if a Member of Council) shall retire annually. The members who shall retire shall be those longest in office, except as provided in Rule 77. Retiring Members of Council who have served for two terms in succession (four years) shall not be eligible for re-election until the next annual election, when they will be eligible.

Rule 72.—The composition of the Council shall be as follows:—

(*a*) Not less than sixteen shall be elected from the technical or scientific grades of the R.Ae.S.—that is to say, from among the Fellows, Associate Fellows and Associates.

(*b*) Of these sixteen, four at least shall be Fellows.

Rule 73.—Nominations of candidates for election to the Council must be received by the Secretary not less than twenty-one days before the Annual General Meeting, with an intimation in writing by the candidates that they are willing to serve. Nominations must be signed by one supporter and two seconders, who must be each entitled to vote in the R.Ae.S.

Fellowship

Members are reminded that under the Rules election to Fellowship is made annually and that all nominations must be received by March 1st at the latest on Form A obtainable from the Secretary.

Binding of Journals

Owing to increased costs, the prices of binding of Journals will be as follows:—

1945 Volume	10s. 0d.
Previous Volumes	12s. 0d.

Journals should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the office of the Society.

Associate Fellowship Examinations

Candidates for the Associate Fellowship Examination are reminded that entries for the May Examination should be received by the Secretary by February 28th.

Lecture Programme

The following are the forthcoming lectures. Members are admitted without tickets, but non-members must obtain tickets through a member.

The Lectures will be held at 6 p.m. in the Lecture Hall of the Institution of Civil Engineers, Great George Street, S.W.1 (by permission of the Council of the Institution). In each case tea will be served at 5.30 p.m.

February 13th—Selection of Engineering Personnel for the Aircraft Industry, by Mr. F. Holliday, B.Sc., F.P.S., A.F.R.Ae.S.

February 28th—The Application of Radio to Civil Aviation, by Sir Robert Watson-Watt, C.B., LL.D., F.R.S., F.R.Ae.S.

March 13th—DISCUSSION ON THE GAS TURBINE.

A full day discussion will be held at which the following papers will be read:—

MORNING SESSION.

11 a.m. The Application of the Gas Turbine to Aircraft Propulsion, by Dr. S. G. Hooker.

12 noon. Turbine-Compounding of the Piston Aero Engine, by Dr. H. Ricardo, F.R.S., F.R.Ae.S.

1-2.30 p.m. Luncheon Interval. Members and visitors to make their own arrangements for lunch.

AFTERNOON SESSION.

2.30 p.m. The Application of the Gas Turbine in its Forms to the Field of Commercial Aviation, by Mr. R. M. Clarkson, F.R.Ae.S.

3.30 p.m. The Application of the Gas Turbine in its Forms to the Field of Military Aviation, by Mr. W. G. Carter, F.R.Ae.S.

4.30-5 p.m. Tea Interval (tea provided).

EVENING SESSION.

5-6.30 p.m. General Discussion and Summing-up by the Chairman.

March 28th—The Electrical Measurement of Strain, by Dr. S. C. Redshaw, F.R.Ae.S.

April 10th—The Silencing of Aircraft, by Mr. N. Fleming, M.A.

April 25th—Modern Aeronautical Materials by Dr. L. Aitcheson, F.R.Ae.S.

May 30th—The Thirty-Fourth Wilbur Wright Lecture will be read by Mr. E. F. Relf, C.B.E., F.R.S., F.R.Ae.S.

Graduates' and Students' Section

February 7th—Technical Activities—A Discussion led by Dr. D. M. A. Leggett, A.F.R.Ae.S., Technical Secretary of the Society.

February 26th—Tailless Aircraft, by Mr. G. H. Lee, A.F.R.Ae.S., of Handley Page, Ltd.

March 20th—Film Show. Radar.

April 16th—Flight Refuelling, by Sir Alan Cobham, K.B.E., A.F.C., Hon. F.R.Ae.S.

May 2nd—Transport Aircraft, by Mr. Frank Radcliffe, F.R.Ae.S., of Handley Page, Ltd.

All Lectures will be read in the Library of the Society, 4, Hamilton Place, W.1, at 7.30 p.m.

Visitors to these lectures are welcomed.

Branch Lectures

BELFAST BRANCH

February 12th—Radio Aids to Navigation, by Mr. S. N. Jackson.

March 12th—Model Tank Testing of Flying-Boat Hulls and Floats, by Mr. L. Smith, A.F.R.Ae.S.

BIRMINGHAM BRANCH

March 6th—Flying-Boats—Their Development and Possibilities, by Mr. A. Gouge, F.R.Ae.S. (Past-President of the Society).

Lectures will be at 7 p.m. in the Birmingham Chamber of Commerce, 95, New Street, Birmingham.

BRISTOL BRANCH

February 19th—Reading of Prize-winning Papers by Junior Members.

March 12th—Industry's Part in Aeronautical Research, by Mr. W. S. Farren, C.B., F.R.S., F.R.Ae.S.

April 2nd—Research in Aeronautics, by Sir Ben Lockspeiser, F.R.Ae.S.

All meetings will be held in the Conference Room, Bristol Aeroplane Company, Ltd., Filton House, at 6.30 p.m.

GLASGOW BRANCH

February 14th—Lecturettes at the Royal Technical College at 7.30 p.m.

LEICESTER BRANCH

February 20th—Low-Drag Aerofoils, by Dr. L. G. Whitehead.

March 6th—Airscrews, by Mr. J. A. C. Williams, A.F.R.Ae.S.

April 10th—Post-War Transport Aircraft Design, by Mr. F. Radcliffe, F.R.Ae.S.

Lectures will be held in Room 45 of Leicester Technical College at 7.30 p.m.

MEDWAY BRANCH

February 11th—Production Organization, by Mr. D. E. Wiseman, in the Mathematical School Hall, Rochester, at 6 p.m.

Annual Subscriptions of Members

Members are reminded that their 1946 subscriptions became due on January 1st, 1946.

The following will be the rates for 1946:—

	Home. £ s. d.	Abroad. £ s. d.
Founder Members ..	2 2 0	2 2 0
Fellows	4 4 0	3 3 0
Associate Fellows ..	3 3 0	2 2 0
Associates	2 2 0*	2 2 0*
Graduates (age 21-25)	2 2 0	2 2 0
,, (age 26-28	2 12 6	2 12 6
Students	1 1 0	1 1 0
Companions ..	2 2 0	2 2 0

* £1 1s. 0d. without Journal.

Election of Members

The following Members were elected recently:—

Associate Fellows

George Urquhart Allan, William Henry Cooper (from Associate), John Philip Golding (from Graduate), Basil Richard Hunter Hicks (from Associate), Alfred Henry Old, Mieczyslaw Murzynski, William John Walker, Harold Robert Wood (from Student).

Companions

Merle William Davenport, Peter Elms (from Student), Philip Thomas Sampson.

Associates

Paul William Baker, John Aubrey Brignell, Alfred Burley, Clifford Leslie Brokenshaw, Arthur Norman Cooper, George Calder Cunningham, Keshah Chandar Dargan, Leslie David Day, Cyril James Faulkner, Thomas Albert Godfrey, Clarence Charles Greensmith, Derek Hanchett-Stamford (from Student), John Leslie Harrison, Keith Hitchins, Wilfred Barwell Holroyd (from Student), Frederick Arthur Houghton (from Student), William Edwin Billing Hurst (from Student), Jack Isaacs, John Oliver Hargreaves Lobley, Julian Lowe (from Student), George Aubrey Marshall, William Walter Allen Mason, Thomas John McTear, Samuel Oliver Peebles, Robin Piercy (from Student), Leslie William Rendlesham, Arthur Rhodes, Alfred Edward Geoffrey Roberts, Julius Shapiro, William Charles Smith, Benjamin Geddes Tyrrell, John Henry Ward, Cyril Edgar Luke Wray.

Graduates

David Stuart Blackmore (from Student), Arthur Capella (from Student), Stanley William Chisman, Mircea Michael Conea (from Student), Ronald Henry Cozens, Ivon William Graham (from Student), Henry Phillip Yeulett Hitch (from Student), William George Moth, Robert Hellyer Perrott, Arthur Clarence Sanderson, Stanley Frank Stapleton (from Student), Francis Todd (from Student), James William Richards Wyman, Jack Waywell (from Student).

Students

Ronald Charles Allen, Raymond Reynolds Atwood, Joyce Mary Bailey, Frank Russell Beach, Anthony John Blaxill, Ronald Courtney Bowers, Frederick Horace Brunning, Michael Thomas Caiger, John Maclaren Campbell, Allan Leopold Clarke, Raymond Charles Darroll, Edward Mark Dowlen, Robert George Eames, Richard Robert Flute, Edmund Fryer, John Worthington Harder, David Harris, Edwin Mosey Harris, Kenneth James Iddon, Ronald Lyell McCallum, Anthony Neil Charles McDonald, Archibald Bathgate McKenzie, Eric Milburn, Michael Christopher Barnes Mitchell, William George Murray, Thomas Eagleton Westwood Nind, Peter Edward Pope, Robert Samuel Potter, Ronald Michael Scannell, Edwin Arnold Shackleton, William Harper Sleigh, Colin Frederick Smith, Thomas William Smith, Cyril Leonard Stephens, Desmond Arthur Treadgold, Brian Hawley Wager, Jeffrey Watkins.

Additions to Library

Pamphlets in italics with location reference following in brackets. Books marked * and ** may not be taken out on loan.

A.d.30.—*The Weybridge Smoke Tunnel. The Airscrew Co., Ltd., Weybridge.* 1945. (Y.1.d.9.)

D.d.32.—*Mechanical Engineering (Careers). Issued by the Ministry of Labour and National Service.* 1945. (P.E.2.b.23.)

E.b.113.—Die Knickfestigkeit von Staben und Stabwerken. Julius Ratzersdorfer. J. W. Edwards Inc. U.S.A. (Copyright 1936, J. Springer, Vienna.) $8.80.

E.E.b.84.—*De Havilland Gipsy Engines. Series* 30, 50, 70. *De Havilland Engine Co., Ltd.* 1946. (Y.7.d.D.)

E.E.b.85.—*De Havilland Gipsy Engine. Gipsy Major* 10. *De Havilland Engine Co., Ltd.* 1946. (Y.7.d.D.)

E.E.b.86.—*De Havilland Gipsy Engine. Gipsy Queen* 11. *De Havilland Engine Co., Ltd.* 1946. (Y.7.d.D.)

E.E.c.78.—Aircraft Engines, Vol. I (2nd Edition revised). A. W. Judge. Chapman & Hall. 1945. 28/-.

F.c.29.—Tables for Measurement of Oil. Institute of Petroleum. 1945.

I.c.(R)30-34.—Applied Mathematics and Mechanics. (In Russian: Precis in English and/or French.) Vol. 7, Nos. 2-6. Various authors. Head Technical-Theoretical Press, Moscow. 1945.

L.d.108.—Aerial Navigation. H. E. Benham. John Wiley & Sons Inc., New York. 1945. $4.00.

Q.a.164.—Index Aeronauticus, Nos. 11 & 12, Nov., Dec. Ministry of Aircraft Production. 1945.

Q.a.165.—Index Aeronauticus, No. 1, Jan., Ministry of Aircraft Production. 1946.

Q.c.45.—*Report of the British Council.* 1945. (P.Q.1.c.1.)

S.e.115.—Flat-Top (The Story of an Escort Carrier). F. D. Ommanney. Longmans, Green & Co., Ltd. 1945. 3/6.

*T.b.96.—Memoirs of Gordon Shephard. Shane Leslie (Editor). Privately Printed. 1924.

*X.b.153.—Year Book of the Royal Society, 1940. Morrison & Gibb, Ltd. 5/-.

*X.f.1.—Holy Bible, The. Cambridge University Press. 40/-.

J. LAURENCE PRITCHARD,
Secretary.

Made and Printed in Great Britain by the Lewes Press, Lewes, Sussex.

TECHNOLOGY DEPT.

THE ROYAL AERONAUTICAL SOCIETY

4, HAMILTON PLACE, PICCADILLY, LONDON, W.1

MARCH NOTICES 1946

JOURNAL PREMIUM AWARDS

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the *Journal* and the Council hope that members (or non-members) will contribute papers on their own special subjects.

Contents of the March Journal

Aircraft Engine Oil Cooling, by F. Nixon, B.Sc.(Hons.), M.S.A.E., Fellow.

Ball and Taper Roller Bearings, by Dr. M. S. Frenkel (translated by P. Meyer, B.Sc.).

Annual General Meeting

Notice is hereby given that the Annual General Meeting of the Royal Aeronautical Society, with which is incorporated the Institution of Aeronautical Engineers, will be held on Saturday, 30th March, 1946, at 2.45 p.m., in the Offices of the Society, 4, Hamilton Place, London, W.1.

AGENDA

1. To read the Notice convening the Meeting.
2. To receive and deliberate upon the Report of the Council on the state of the Society and the Balance Sheets of Aerial Science Limited and Aeronautical Trusts Limited for the year ended 31st December, 1945.
3. To receive the nominations for Council for the years 1946-47.
4. To announce the List of Fellows elected by the Council in accordance with Rule 4.
5. To elect the Auditors for the ensuing year for Aerial Science Limited and Aeronautical Trusts Limited.
6. Any other business.

By order of the Council,

J. LAURENCE PRITCHARD,

Secretary.

Light refreshments will be served after the meeting.

Annual General Meeting: Graduates and Students' Section

The Annual General Meeting of the Graduates and Students' Section will be held on Friday, the 29th of March, 1946, at 7.30 p.m., in the Offices of the Society, 4, Hamilton Place, London, W.1.

AGENDA

1. To receive report of the Hon. Secretary.
2. To elect the Officers and Committee for the year 1946-47 (nominations should be received by the Hon. Secretary not later than 22nd March, 1946).
3. To consider any other business.

E. J. N. ARCHBOLD,

Hon. Secretary.

The Wilbur Wright Memorial Lecture, 1946

The Thirty-fourth Wilbur Wright Memorial Lecture, to be read on the 30th May by Mr. E. F. Relf, C.B.E., F.R.S., F.R.Ae.S., Principal of the College of Aeronautics, will be entitled " Recent Aerodynamic Developments."

Correction to the February Journal

We regret that in the messages of congratulation received by the Society on its Eightieth Anniversary, Mr. Charles H. Colvin's name was incorrectly given as " Colville."

Lecture Programme

The following are the forthcoming lectures. Members are admitted without tickets, but non-members must obtain tickets through a member.

The Lectures will be held at 6 p.m. in the Lecture Hall of the Institution of Civil Engineers, Great George Street, S.W.1 (by permission of the Council of the Institution). In each case tea will be served at 5.30 p.m.

March 13th—DISCUSSION ON THE GAS TURBINE.

A full day discussion will be held at which the following papers will be read:—

MORNING SESSION.

11 a.m. The Application of the Gas Turbine to Aircraft Propulsion, by Dr. S. G. Hooker.

12 noon. Turbine-Compounding of the Piston Aero Engine, by Dr. H. Ricardo, F.R.S., F.R.Ae.S.

1-2.30 p.m. Luncheon Interval. Members and visitors to make their own arrangements for lunch.

AFTERNOON SESSION.

2.30 p.m. The Application of the Gas Turbine in its Forms to the Field of Commercial Aviation, by Mr. R. M. Clarkson, F.R.Ae.S.

3.30 p.m. The Application of the Gas Turbine in its Forms to the Field of Military Aviation, by Mr. W. G. Carter, F.R.Ae.S.

4.30-5 p.m. Tea Interval (tea provided).

EVENING SESSION.

5-6.30 p.m. General Discussion and Summing-up by the Chairman.

March 28th—The Electrical Measurement of Strain, by Dr. S. C. Redshaw, F.R.Ae.S.

April 10th—The Silencing of Aircraft, by Mr. N. Fleming, M.A.

April 25th—Modern Aeronautical Materials by Dr. L. Aitchison, F.R.Ae.S.

May 30th—The Thirty-Fourth Wilbur Wright Lecture will be read by Mr. E. F. Relf, C.B.E., F.R.S., F.R.Ae.S.

Graduates' and Students' Section

March 20th—Film Show. Radar.

April 16th—Flight Refuelling, by Sir Alan Cobham, K.B.E., A.F.C., Hon. F.R.Ae.S.

May 2nd—Transport Aircraft, by Mr. Frank Radcliffe, F.R.Ae.S., of Handley Page, Ltd.

All Lectures will be read in the Library of the Society, 4, Hamilton Place, W.1, at 7.30 p.m.

Visitors to these lectures are welcomed.

Branch Lectures

BELFAST BRANCH

March 12th—Model Tank Testing of Flying-Boat Hulls and Floats, by Mr. L. Smith, A.F.R.Ae.S.

BIRMINGHAM BRANCH

March 6th—Flying-Boats—Their Development and Possibilities, by Mr. A. Gouge, F.R.Ae.S. (Past-President of the Society).

Lectures will be at 7 p.m. in the Birmingham Chamber of Commerce, 95, New Street, Birmingham.

BRISTOL BRANCH

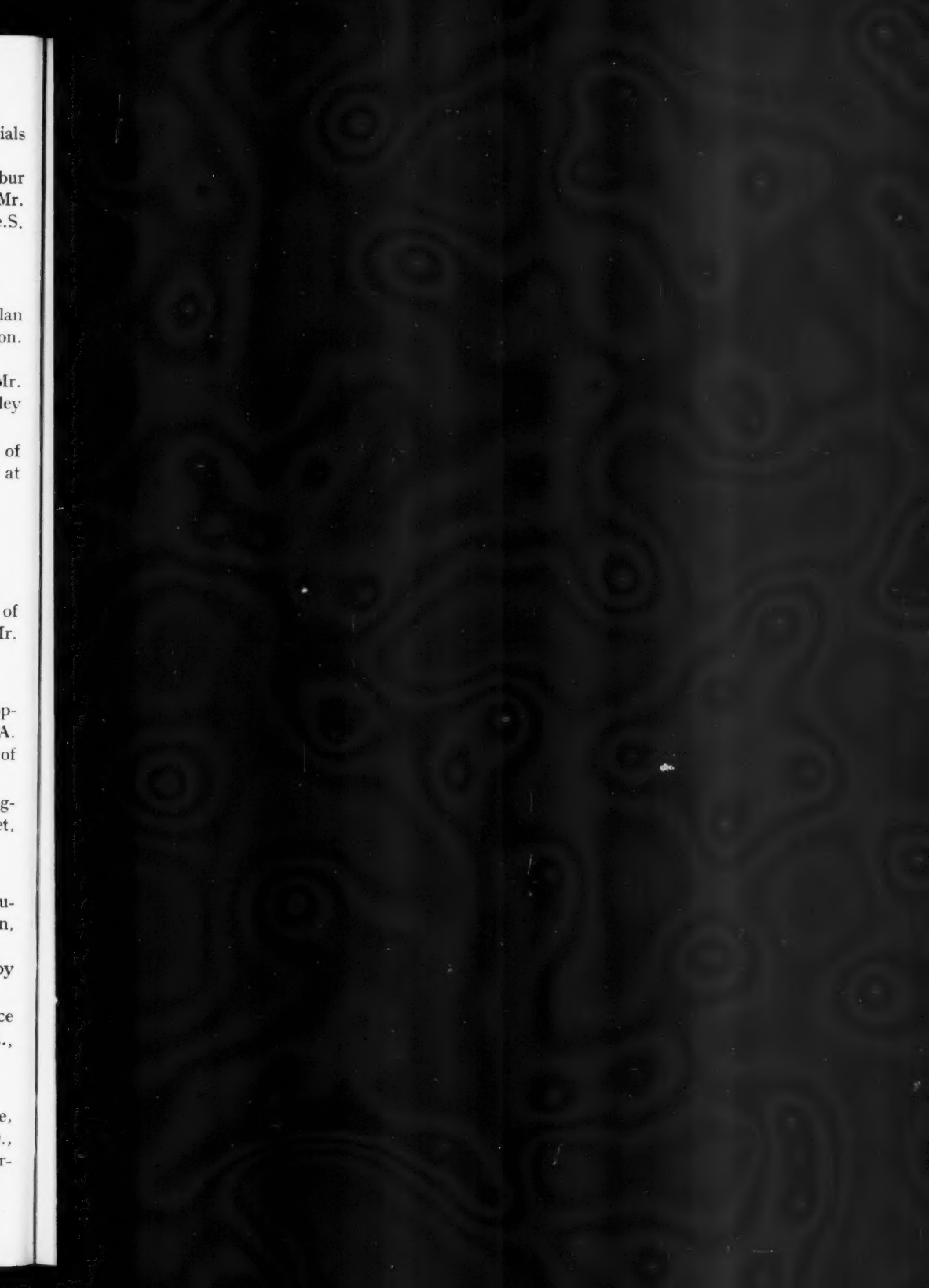
March 12th—Industry's Part in Aeronautical Research, by Mr. W. S. Farren, C.B., F.R.S., F.R.Ae.S.

April 2nd—Research in Aeronautics, by Sir Ben Lockspeiser, F.R.Ae.S.

All meetings will be held in the Conference Room, Bristol Aeroplane Company, Ltd., Filton House, at 6.30 p.m.

COVENTRY BRANCH

March 21st—Master Bombing Technique, by Wing Commander Northrop, D.S.O., D.F.C. Chairman: C. K. Turner-



Hughes, A.R.Ae.S. (Chief Test Pilot, A.W.A., Ltd.).

April 18th—Annual General Meeting and Film Show.

Meetings will be held in the Council Staff Canteen (Old Gulson Library) commencing at 7 p.m. prompt.

LEICESTER BRANCH

March 6th—Airscrews, by Mr. J. A. C. Williams, A.F.R.Ae.S.

April 10th—Post-War Transport Aircraft Design, by Mr. F. Radcliffe, F.R.Ae.S.

Lectures will be held in Room 45 of Leicester Technical College at 7.30 p.m.

MANCHESTER BRANCH

March 21st—Rockets, by Mr. W. G. Perring, F.R.Ae.S.

April 25th—Jet Engines, by Air Commodore F. Whittle, F.R.Ae.S.

SOUTHAMPTON BRANCH

April 3rd—Flying-Boats—Their Development and Possibilities, by A. Gouge, F.R.Ae.S.

The Lecture will be held at University College, Southampton, at 7 p.m.

Coventry Branch

SCHOLARSHIPS IN AERONAUTICAL ENGINEERING

The Coventry Branch has revived the practice of granting scholarships to students at the local Technical College. The value of each Scholarship is £6 over two years and the candidate is allowed to select books to this value from a list supplied by the Branch.

A condition of the award is that the candidates must sit for the Associate Fellowship Examination, and if successful, undertake to be members of the Society in the appropriate grade for a minimum period of five years.

Two Scholarships have been awarded for 1946-1947. They are to:—

Brian John Green, 14, Kenpas Highway, Green Lane, Coventry.

George Norman Coulthard, 124, Tonbridge Road, Whitley, Coventry.

Election of Members

The following Members were elected recently:—

Associate Fellows

Hannah Gwendolen Alston, Malcolm Webster Anderson, Cecil Beardsley Baker, Frank Geoffrey Barlow, Jadavsingh Bankatsingh Bayas, Stephen Archbold Bergen, Derek Roy Bettison (from Graduate), William Herbert Brown (from Graduate), Alan William Scott Clarke, Roger Kendal Cushing, John Douglas Hayhurst, Hugh McLennan Kendal (from Graduate), Graham Wright Kinloch, Julian Leslie (from Graduate), William Godfrey Lewis, Karl Antony de Lisser, Ivan Charles McOran Campbell (ex-Graduate), Ram Anugrah Prasad Misra, Vivian Ernest Saunders Mitchell, Charles Edward Onions (from Graduate), John Lewis Orr (ex-Student), Dennis Edwin Piper (from Graduate), Madhukar Hari Paranjpye, Colin Rawden, Frederick Vere Kent Sutton (from Graduate), Eric William Thomas Stow, Henry Donald Strawson, James Swan, Cyril Rex Turner, James Norman Verner (from Graduate), Charles Timothy Wilkins.

Companions

Edward Anthony George Chlala, Basil Richards Claydon, Edward Bagley Gale, Chia-Tao Loh, William Reginald Verdon Smith, Cyril Francis Trigg (from Graduate).

Associates

George Edward Archdale, Eric Herbert Chetwin Baker, Eric Barraclough, Eric Beal, Cyril Leonard Bessey, Ernest Edwin Brown, Robert Brown, Arthur Fellowes Buck, Albert Catton, Stanley Cooper, Alan Edgar Crawford (from Student), Henri G. Denamur, Frank Ridsdale Dixon, Gerald Sinclair Evatt, George Albert Ford, Charles Wilfred James Gibbs, Eric Martin Goodger (from Graduate),

Samuel Herbert John Hammond, Frank Harris, Ronald Frank Haywood, Robert Waldenar Henderson, Frederick George Conant Henwood, Harold Taylor Hill, Eric William Humphreys, Norman Eric Denis Hurst, Norman Hunt, George Lindsay-Murray, Alexander Ian McRitchie, Robert Mervyn Manfield, Edward Bertram Millward, Samuel Frederick Mortimer, Gerald Bernard Oakes, Jack Holbrook Oliver, Richard John Bennett Pearse, Eric Shackleton, John Joseph Veasey, Edwin Perry Wood, Stuart Spencer Wyllie (from Student), Cecil Stanley Yeates.

Graduates

Peter Frederick Ashwood (from Student), Kenneth Frank Callis (from Student), Bernard Crossland (from Student), Geoffrey Wallis Dearsley (from Student), John Roland Fox (from Student), Michael Alec Garnett (from Student), John Kenneth Gilbert (from Student), Kenneth Lewis Hodkinson (from Student), Gordon Thomas Hudson (from Student), Ruphail Ishkinazi, Douglas Royston Farleston Jones, Hans Jurgen Peter Bruno Kahn (from Student), Arthur Charles Leftley, Ian Alfred Thomas Lumsden (from Student), Edward Frank Mitchell (from Student), Dennis Gordon Plowright, Donald Sydney Thomas, Stanley Warren (from Student), Kenneth Douglas Wells (from Student).

Students

Howard Godfrey Rex Adams, Michael Henry Beeching, Frederick Nelson Brown, Thomas Norman Corkill, Alan William Nisbett Garratt, Dennis Patrick Flynn, Francis Ross Gibb, John Harvey Goodenday, William Grundy, Peter Ambrose Hearne, Philip Norman Holt, Alfred Hucknall, Francis George Irving, Norman Francis Lawrence, Dilwyn Lewis, Alastair McKay, Jeffrey Nicholas Montgomery, Keith Jones Oldham, Peter Jack Palmer, Ralph Ramsay, Harry Rewitch, Alwyne Edward Thornton, Christopher Hugh Walker, Michael Henry Lewin Waters, Kenneth Ronald Welling, Stanley Wood.

Associate Fellowship Examination Results

The following were successful in the Associate Fellowship Examination held in December, 1945:—

Anderson, J. A., Theory of Internal Combustion Engines; Baines, C. R., Pure Mathematics, Theory of Machines; Bishop, A. R., Aircraft Materials; Buchan, A. L., Applied Mathematics, First Place; Cadie, F. M. G., Applied Mathematics; Chifrine, S. B. S., Applied Mathematics; Cohen, J. A., Applied Mathematics, Theory of Machines, Design (Engines); Curties, M. C., Pure Mathematics, Aerodynamics, First Place, Aircraft Instruments, First Place; Dolezal, J., Applied Mathematics; Ebershardt, P., Pure Mathematics; Evans, J. D., Aerodynamics; Evans, R. G., Pure Mathematics, Strength of Materials, First Place, Theory of Machines; Kaye, B., Pure Mathematics; Kendall, R., Strength of Materials; King, E. D., Applied Mathematics, Design (Engines); Little, G. W., Applied Mathematics; Littlechild, A. D., Applied Mathematics, Theory of Machines, First Place, Tie, Design Engines; Milligan, F. J., Aircraft Instruments, Aircraft Materials; Mitchell, A. J. L., Pure Mathematics; Mucha, E., Pure Mathematics; Naismith, S. T., Theory of Internal Combustion Engines, First Place; Namjoshi, M. V., Strength of Materials; Posner, M., Applied Mathematics, Design (Engines); Robertson, F. H., Aerodynamics; Robinson, R. G., Applied Mathematics, Strength of Materials, Aircraft Materials, First Place; Ronson, G. L., Applied Mathematics; Saravanos, B., Strength of Materials; Saunders, G. C., Design (Engines), Theory of Internal Combustion Engines; Stanley, G., Theory of Machines, First Place, Tie; Subbarao, H. Y., Theory of Internal Combustion Engines; Thomson, R., Navigation; Walsh, R. H., Theory of Internal Combustion Engines,

Design (Engines); Wood, K. F., Pure Mathematics, Aerodynamics.

Acknowledgments

The Council acknowledge with thanks the gift of models from: Blackburn Aircraft Limited, F. A. Hughes and Company, Limited, and D. Napier and Son, Limited.

They also acknowledge with thanks the gift of photographs from: Blackburn Aircraft Limited, the De Havilland Aircraft Company, Limited, Gloster Aircraft Company, Limited, Miles Aircraft Limited, Percival Aircraft Limited, A. V. Roe and Company, Limited, Rolls-Royce Limited, and Vickers-Armstrongs Limited.

The gift of books and photographs are acknowledged with thanks from Mr. J. W. Dobson, Associate Fellow, and books from Mr. F. J. Field, Mr. E. M. Goodyer, Mr. S. E. Veale and Mr. W. Adam Woodward.

Back numbers of The Journal and three "Titles and References" from Mr. T. J. Roper are acknowledged with thanks.

Additions to the Library

Pamphlets in italics with locating reference following in brackets. Books marked * or ** may not be taken out on loan.

*A.A.—Aeronautical Research Committee: (List of) Reports and Memoranda published between 1st July, 1939, and 30th June, 1945. Ministry of Aircraft Production, Aeronautical Research Council. H.M. Stationery Office. 1946. 1/-.

BB.f.61.—Scientific Instruments. H. J. Cooper (Editor). Hutchinson. 1946. 25/-.

BB.f.62.—The Gyroscope and its Applications. M. Davidson (Editor). Hutchinson. 1946. 21/-.

**B.a.356 (I).—Gli - Aeroplani Caproni. Gianni Caproni. Emilio Bestetti, Milan. 1937.

E.a.15.—Elementary Applied Mechanics. A. Morley and W. Inchley. Longman's Green. 1938.

E.d.27.—Production Illustration: The Techniques and Applications of Perspective Engineering Drawings. John Treacey. John Wiley & Sons, Inc., N.Y. 1945. $4.

EE.h.16.—*"Jets." J. J. Partridge and C. J. Goulding. National Association of Spotters Clubs.* 1945. 1/6. (PEE.4.b.)

I.a.40.—Mathematics for Engineers, Part I. W. N. Rose. Chapman & Hall. 1939. 10/6.

M.b.54.—*Report of the Television Committee* 1943. *H.M. Stationery Office.* 1945. 6*d.* (P.M.2.a.4.)

Q.a.165. — U.S. National Bureau of Standards: Supplement List of Publications, 1/1/42-30/6/44. U.S. Government Publications. H.M. Stationery Office. 1944. 1/-.

Q.c.46.—*Higher Technological Education. Ministry of Education. H.M. Stationery Office.* 1945. 6*d.* (P.Q.1.c.)

**R.c.284.—Short Bros. Aircraft. A Photographic Record of Aircraft Designed and Constructed in the Period 1908-1944. Short Bros. (Rochester and Bedford), Ltd. 1946.

UB.5/1.—German Activities in the French Aircraft Industry: Report on (Aircraft). Combined Intelligence Objectives Sub-Committee. H.M. Stationery Office. 1945.

UB.5/2.—Suddeutsche Kabelwerke Mannheim, Report on (Misc. Chemicals). Combined Intelligence Objectives Sub-Committee. H.M. Stationery Office. 1945.

UB5/3.—Deutsche Dunlop Gummi Compagnie A.G., Hanau-am-Main, Report on (Misc. Chemicals). H.M. Stationery Office. 1945.

UB.5/4.—I.G. Farbenindustrie, Hoechst Main, Report on (Fuels and Lubricants). Combined Intelligence Objectives Sub-Committee. H.M. Stationery Office. 1945.

UB.5/5.—I.G. Farbenindustrie, A.G. Plant Hoechst Main, Report on (Misc. Chemicals). Combined Intelligence Objectives Sub - Committee. H.M. Stationery Office. 1945.

UB.5/6.—Robert Bosch, Stuttgart and Fuerbach, Report on (Metallurgy). Combined Intelligence Objectives Sub-Committee. H.M. Stationery Office. 1945.

UB.5/7.—Die Staatliche Materialprufungsanstalt an der Technische Hochschule, Stuttgart, Report on (Fuels and Lubricants). Combined Intelligence Objectives Sub-Committee. H.M. Stationery Office. 1945.

UB.5/8.—Plant of Klocknerwerke A.G., Castrop-Rauxel. Report on (Fuels and Lubricants). Combined Intelligence Objectives Sub - Committee. H.M. Stationery Office. 1945.

UB.5/9.—Steeg and Reuter, Bad Homburg, Report on (Radar, Physical and Optical Instruments). Combined Intelligence Objectives Sub-Committee. H.M. Stationery Office. 1945.

UB.5/10.—Felten and Guilleaume Carlswerke, Cologne-Mülheim. Report on (Misc. Chemicals). Combined Intelligence Objectives Sub-Committee. H.M. Stationery Office. 1945.

UB.5/11.—Klein, Schanglin and Becker A.G., Hydraulic Couplings and Torque Converters, Report on (Armoured Fighting Vehicles). Combined Objectives Intelligence Sub - Committee. H.M. Stationery Office. 1945.

UB.5/12. — German Research and Development in the Radio Field, Lyons Area (Radar). Combined Intelligence Objectives Sub - Committee. H.M. Stationery Office. 1945.

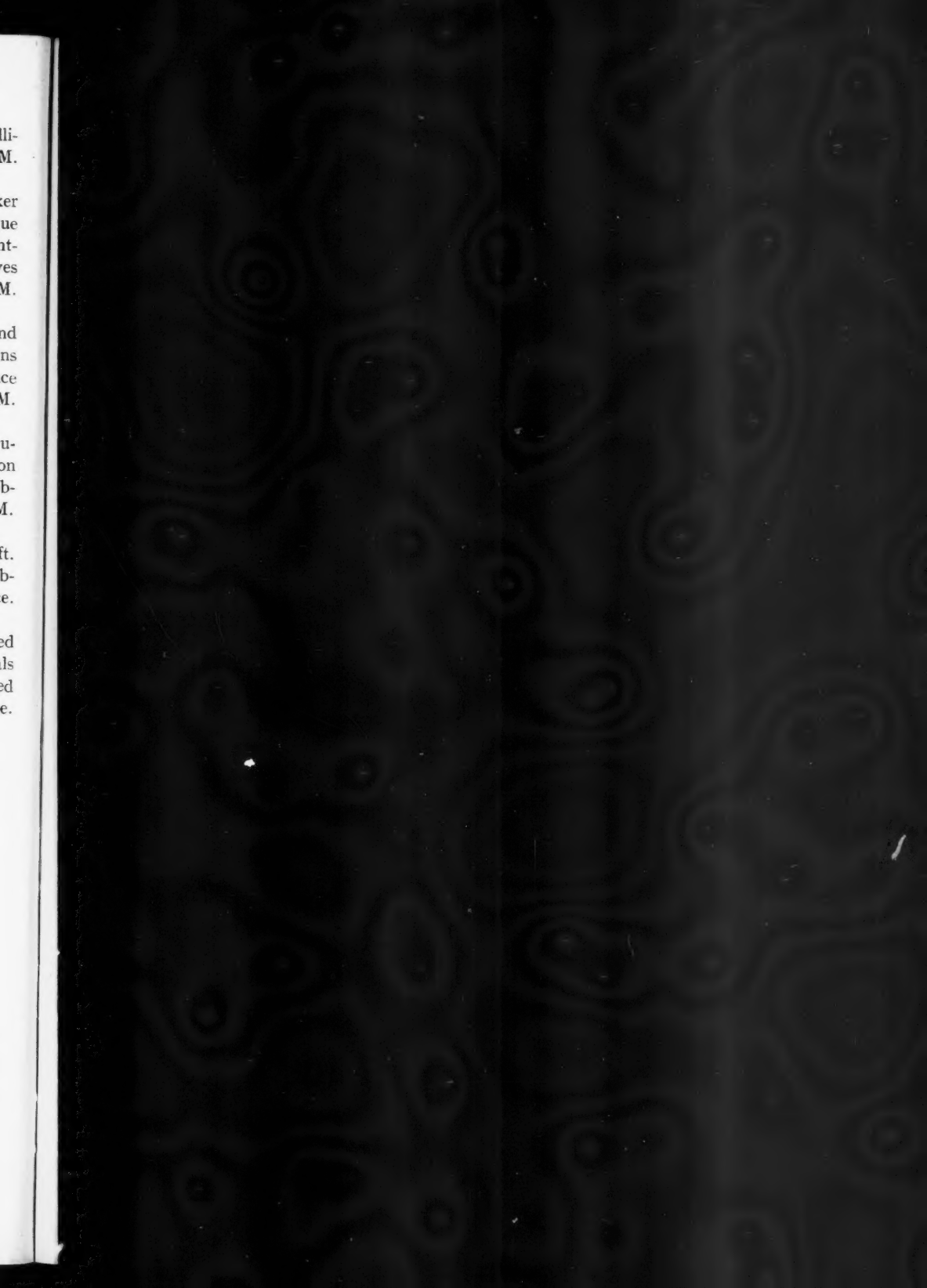
UB.5/13.—Physical and Optical Instrument Targets, Paris Area, Report on (Radar). Combined Intelligence Objectives Sub - Committee. H.M. Stationery Office. 1945.

UB.5/14.—The Horten Tailless Aircraft. Combined Intelligence Objectives Sub-Committee. H.M. Stationery Office. 1945.

UB.5/15.—Fischer Tropsch and Allied Processes, Report on (Misc. Chemicals and Fuels, and Lubricants). Combined Intelligence Objectives Sub-Committee. H.M. Stationery Office. 1945.

J. LAURENCE PRITCHARD,
Secretary.

Made and Printed in Great Britain by the Lewes Press, Lewes, Sussex.



TECHNOLOGY DEPT.

THE ROYAL AERONAUTICAL SOCIETY

4, HAMILTON PLACE, PICCADILLY, LONDON, W.1

APRIL NOTICES 1946

JOURNAL PREMIUM AWARDS

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the *Journal* and the Council hope that members (or non-members) will contribute papers on their own special subjects.

Contents of the April Journal

Dr. F. W. Lanchester, LL.D., Hon. Fellow R.Ae.S., Hon. Mem. Inst. Auto.E., Hon. Mem. Inst. Mech.E., Assoc. Inst. N.A. Obituary.

" Selection of Engineering Personnel for the Aircraft Industry," by F. Holliday, B.Sc., F.P.S., A.F.R.Ae.S.

" Response in Yaw," by E. J. N. Archbold, B.Sc., Grad. R.Ae.S., Tech. M.I.Ae.S., and Keiran T. McKenzie, Stud. R.Ae.S.

" The de Havilland Wing Test Rig," by W. Hampton, Graduate.

Reviews.

Journal Premium Awards

In January, 1945, the Council decided to set aside an annual sum of £250 for the award of premiums for papers published in The Journal. The awards for 1945 have now been made. Premium awards of twenty-five guineas have been made to the following:—

A. J. Dilloway, Graphics of World Aviation.	March Journal
W. Tye, B.Sc., A.F.R.Ae.S., Airworthiness of Civil Aeroplanes.	June Journal

Awards of ten guineas have been made to the following:—

C. H. Flurscheim, B.A., M.I.E.E., and J. A. Nott, B.Sc., A.M.I.E.E. (ten guineas each), Aircraft Circuit Breakers.	November Journal
H. H. Gardner, B.Sc., Wing Testing—A Method of Testing the Wing Structure of Large Aircraft, adopted by Vickers-Armstrongs.	September Journal
Major F. M. Green, Value of Weight Saving in Airliners.	April Journal
R. G. Manley, B.Sc., Some Notes on Vibration Analysis.	July Journal
S/Ldr. J. G. M. Pardoe, Note on Aircraft Structural Failures and Factors for Safety.	April Journal
The late S/Ldr. J. R. Tobin, Test Flying (A lecture given to the Brough Branch of the Society).	June Journal
F. J. Turton, B.Sc., A.R.C.S., The Euler Critical Load for Pinned-Pinned Polynomial Tapered Struts.	October Journal
P. B. Walker, M.A., Ph.D., Retardation Efficiency by Shock Absorber and Arrester Gear.	October Journal
L. G. Whitehead, Ph.D., Stresses in Ring Structures.	October Journal

Premium awards will be made annually to authors of papers published in the Journal, irrespective of nationality and whether or not the authors are members of the Society.

The Branch Prize

The Branch prize of twenty guineas awarded annually for the best paper read before a Branch, has been awarded for 1945 to Mr. Norman A. White, G.I.Mech.E., G.I.A.E., F.R.S.A., Graduate, for his paper "The Future Development of Aircraft for Civil Aviation" read before the Luton Branch.

This prize is open to any member of the Society or of any Branch.

The Usborne Prize

Mr. O. R. Ballard, Student, has been awarded the Usborne prize for 1945 for his paper "The Cooling of High-Powered Aero-Engines."

This prize is offered annually, at the discretion of the Council, for the best paper by a Student on some subject connected with aero-engines. The value is five guineas.

Correction to February Journal

We regret that in the February Journal Mr. Daniel McVey was incorrectly referred to as the "Hon. Daniel McVey, Minister of Civil Aviation, Commonwealth of Australia." He was, in fact, Director-General of Civil Aviation.

Mr. McVey has since resigned from that post, but is still Director-General of Aircraft Production.

Air Marshal Richard Williams, C.B., C.B.E., D.S.O., is now the Director-General of Civil Aviation in Australia.

Advance Proof

Copies of the lecture to be given on the 25th April by Dr. L. Aitchison, F.R.Ae.S., on Aeronautics and the Metallurgist will be available by the 15th April.

An Air Mail Collection

At the suggestion of many members, a collection of First Day air mail covers, general air mail covers and air mail stamps is being formed by the Society. This collection will be available for inspection by members at the headquarters of the Society as soon as it has reached a suitable size.

The Society would be grateful if any members who have covers or stamps they do not require would present them to the Society to assist in the formation of this collection.

History of the Society

A few copies are left of the history of the Society which was prepared in connection with the Eightieth Anniversary Celebrations. They may be obtained from the offices of the Society, price five shillings (5/3 post paid).

Lecture Programme

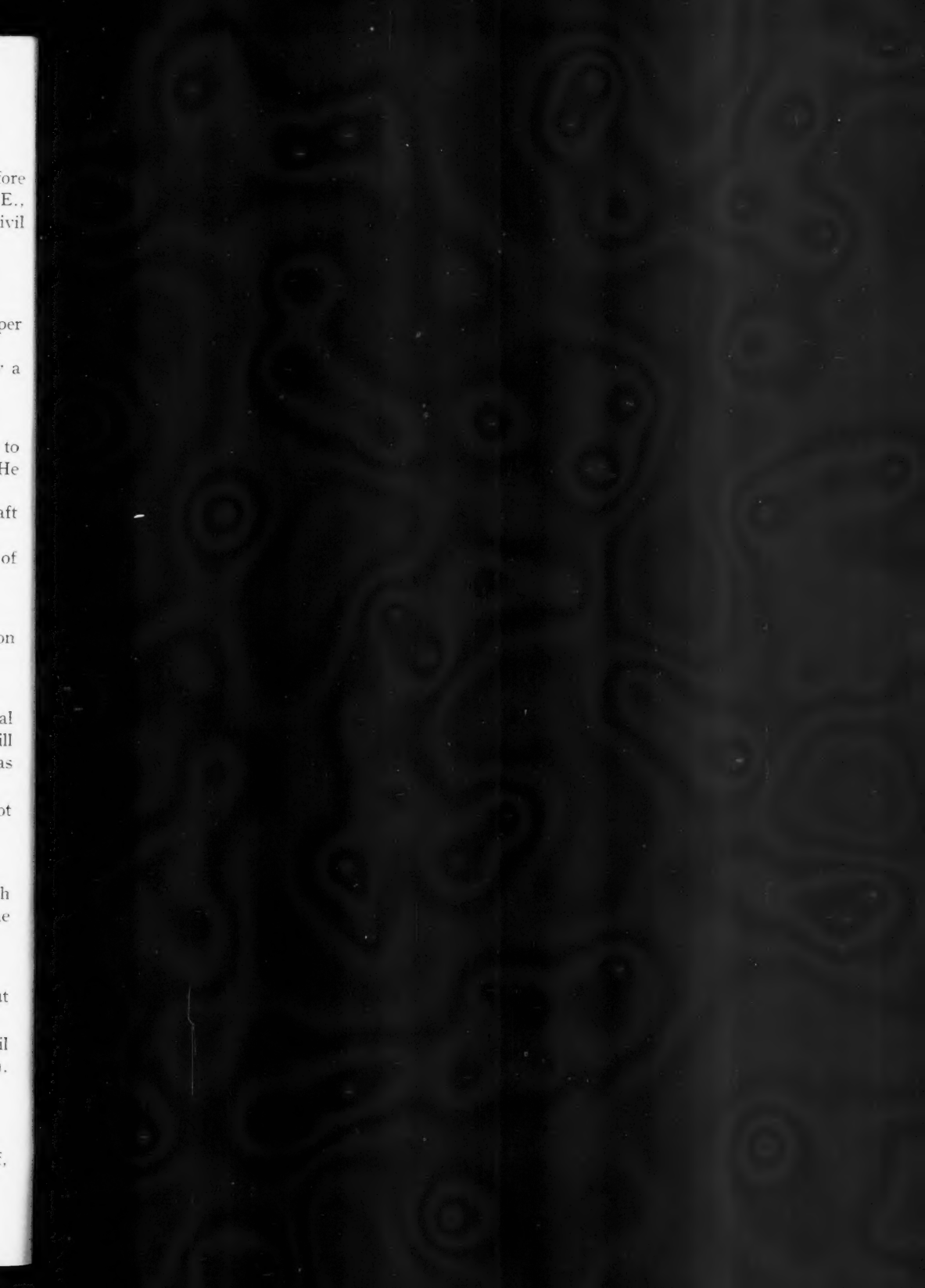
The following are the forthcoming lectures. Members are admitted without tickets, but non-members must obtain tickets through a member.

The Lectures will be held at 6 p.m. in the Lecture Hall of the Institution of Civil Engineers, Great George Street, S.W.1 (by permission of the Council of the Institution). In each case tea will be served at 5.30 p.m.

April 10th—The Silencing of Aircraft, by Mr. N. Fleming, M.A.

April 25th—Aeronautics and the Metallurgist, by Dr. L. Aitchison, F.R.Ae.S.

May 30th—The Thirty-Fourth Wilbur Wright Lecture will be read by Mr. E. F. Relf, C.B.E., F.R.S., F.R.Ae.S.



Graduates and Students' Section

April 16th—Flight Refuelling, by Sir Alan Cobham, K.B.E., A.F.C., Hon.F.R.Ae.S.

May 2nd—Transport Aircraft, by Mr. Frank Radcliffe, F.R.Ae.S., of Handley Page, Ltd.

All Lectures will be read in the Library of the Society, 4, Hamilton Place, W.1, at 7.30 p.m.

Visitors to these lectures are welcomed.

Branch Lectures

BRISTOL BRANCH

April 2nd—Research in Aeronautics, by Sir Ben Lockspeiser, F.R.Ae.S.

All meetings will be held in the Conference Room, Bristol Aeroplane Company, Ltd., Filton House, at 6.30 p.m.

COVENTRY BRANCH

April 18th—Annual General Meeting and Film Show.

Meetings will be held in the Council Staff Canteen (Old Gulson Library) at 7 p.m.

DERBY BRANCH

April 1st—Aircraft Engine Oil Cooling, by Mr. F. Nixon, B.Sc., F.R.Ae.S.

May 6th—Paper by Col. W. C. Devereux, F.R.Ae.S. (Managing Director, Almin, Ltd.).

Meetings will be held in the Rolls-Royce Welfare Hall, Nightingale Road, at 7 p.m.

GLASGOW BRANCH

April 11th—Scotland's Place in World Transport, by Group Captain McIntyre.

The meeting will be held at the Royal Technical College, George Street, Glasgow, at 7.30 p.m.

LEICESTER BRANCH

April 10th—Post-War Transport Aircraft Design, by Mr. F. Radcliffe, F.R.Ae.S.

Lectures will be held in Room 45 of Leicester Technical College at 7.30 p.m.

LUTON BRANCH

April 3rd—Navigational Aids, by Mr. Drake (Drake Navigator Company).

MANCHESTER BRANCH

April 25th—Jet Engines, by Air Commodore F. Whittle, F.R.Ae.S.

READING BRANCH

May 8th—The Evolution of Fighter Tactics, by Squadron Leader J. Nelson, A.F.C.

The Lecture will be held at Miles Aircraft, Ltd., The Aerodrome, Reading, at 6 p.m.

SOUTHAMPTON BRANCH

April 3rd—Flying-Boats—Their Development and Possibilities, by A. Gouge, F.R.Ae.S.

The Lecture will be held at University College, Southampton, at 7 p.m.

Hatfield Branch

The Hatfield Branch of the Society, which has been in abeyance during the War, is resuming its activities. A lecture programme will be arranged for this year. Membership for 1946 will be limited to 175, but it is hoped to increase this number next year.

The Honorary Secretary is Mr. H. W. L. Calder, A.F.R.Ae.S., The de Havilland Aircraft Co., Ltd., Hatfield, Herts.

Election of Members

The following members were elected recently:—

Associate Fellows

William Atkinson Adam, Desmond Rene Fitzgerald Barron (from Student), John Raymond Batty (from Graduate), Frank Norman Bartlett Bennett (from Student), Dennis Walter Brinkworth, Jan-Flawiusz Bortkiewicz, John George Bradley (from Graduate), Cecil George Fitzroy Brown (Ex-Student), William Herbert Brown (from Graduate), George Wolfe Bubb, Herbert William Leslie Calder (from Associate), Anthony Frank Carr (from Graduate), Peter Charles Cleaver (from Student), Albert Day, Duncan Liddaird Evans, Herbert William Fudge, Robert Reginald Green, Robert George Irons (from Graduate), Bernard David Jones, Erwin Sophron Julius Krauss, Geoffrey Michael Lilley (from Gradute), Cyril George Frederick Long, Alexander James McCulloch, Jesse McKenna, Leslie Marshall, Ernest Milner, Ronald Charles Pankhurst, Jerzy Przybylski, Thomas Arthur William Stern, William Arthur Summers (from Associate), Ronald Hain Taylor, Robert Edward Tiffin, Christopher Tom Walkington (from Associate), Frederick Watkin, Charles Frank Watkinson (from Graduate), Ian Neville Way (from Student), Arthur White, Gilbert Andrew Whitehead, Hieronim Zuber.

Companions

Charles Kenneth Bonner (from Graduate), Edward Cyril Bowyer, Sir Harry Brittain, Leslie Austin Henson, T. K. S. Murthy, Huseyin Unsal, Hulki Yanat.

Associates

Albert Adams, Douglas George Allison, George Beck, Eric Beal, Wilfred Owen Beer, William Dennis Blackburn, Royston Leigh Bonner, Eric Melrose Brown, Geoffrey Austen Chamberlain, Donald Clayson, Cyril Edward Allen Colder, Arthur Harold Cooke, Annie Davis, Lakshmikanto Dey, David Arthur Dodson, Jiri Dolezal, John Goulding, Sidney Walter Griffin, Clement Francis Sidney Hague, Leslie Austin Hancox, James Athol Harrington, Jack Jackman, John Heley, Gwyn Rowland Hopkins (from Student), Basil Jackson (from Student), Hugh Vincent Kennedy, Howard Charles Laker, William Harold Llewellyn, Ralph Lury, Frederick William Ball Mann, Hubert Charles Maynard, Richard Ernest Mills, Frederick Jack Moden, George Brian Moncrieff-Yeates, Reginald Eycott Nicoll, Trevor Clwyd Parry, George Robert Procter Pearson (from Student), William Holland Pollock, Richard Alfred Prew, Ronald Dominic Price, Douglas Wilfred Ransom, John Cecil Rice, Joseph Alfred Saunt, Douglas Oliver Spratt (from Graduate), William Frederick George Stamp, Henry Taylor, James Frederic Templeton, George Gerwyn Arthur Walters, James Weddup, Cyril Thomas White, John Henry Whiting, Arthur Winter-Hall.

Graduates

Leonard Barley, Ronald John Brocklehurst, Ralph Elwin Roy Broomfield (from Student), Charles Anthony Chapman (from Student), John Carol Collins (from Student), Arthur Ernest Elmer, Raymond Holl (from Student), William Bennett Jarvie, Kenneth Alfred Lowe, Michael John Mott (from Student), Ralph Oakes (from Student), Wilfred Edwin Pearce (from Student), Joyce Theodora Perrott, Peter Robinson, Philip Harold Townshend, John Pryme Uffen (from Student), Vivian Edwin Wilkin.

Students

David George Baker, Harry William Baker, Anthony James Barrett, John Calvert Barrett, Cyril Bell, Gordon Walter Bleasdale, Dennis Herbert Stanley Burton, Ian Stewart

Campbell, John Edward Clough, David Andrew Coomber, Keith Hall, Dennis Alec Head, John Charles Hodge, Colin John James, George Hubert Leslie James, James Leggat, Dennis Owen Luke, John Christie MacDonald, Harbansh Kumar Mathur, Arthur William Nicholls, Philip Robbins, Earle Rhoades, Alan Henry Robinson, Richard Arthur Rubinstein, Robert David Nigel Saunders, Charles John Street, Thomas Frederick Wade, Geoffrey Edward Williams.

Associate Fellowship Examinations

The next Associate Fellowship Examinations will be held on May 21st and 22nd, 1946. Full particulars will be sent direct to all Candidates.

Additions to Library

Pamphlets in italics with location reference following in brackets. Books marked * or ** may not be taken out on loan.

Aa.314.—*Aerodynamics Analysed. T. E. G. Bowden. Harborough.* 1943. 2/-. (PA.1.a.21.)

BB.c.103.—Variable Pitch Propellers. J. A. Kyd. Pitman. 1945. 6/-.

B.a.357.—Hurricane. F. H. M. Lloyd. Harborough. 1946. 7/6.

Be.43.—*Radio Control for Model Aircraft. P. Hunt. Harborough.* 1944. 2/-. (P.B.6.a.8.)

*B.g.146.—Japanese Aircraft. J. Stroud. Harborough. 1945. 25/-.

D.a.B.92.—*Final Act of the Civil Aviation Conference, Bermuda* 1946 *and Agreement between the Government of the United Kingdom and the Government of the United States of America relating to Air Services between their Respective Territories. Secretary of State for Foreign Affairs. H.M. Stationery Office.* 1946. 3d. (P.D.2.a.21).

D.b.247.—British Air Mails: A Chronology of the Air Posts of Great Britain and Ireland. N. C. Baldwin (Editor). Francis J. Field, Ltd. 1935.

D.b.248.—Great Britain and Ireland: Catalogue of Internal Air Mails, 1910-1941. N. C. Baldwin (Compiler). Francis J. Field, Ltd. 1942. 3/6.

Db.249.—Coronation Aerial Post 1911. Francis J. Field and N. C. Baldwin. Francis J. Field, Ltd. 1934.

R.f.100.—*De Havilland Aircraft Co. The First Quarter Century* 1920-45. *De Havilland Aircraft Co.* 1945. 6*d*. (Y.11.iv.a.29.)

TT.a.52.—Second Dog. B. J. Hurren. Harborough. 1946. 8/6.

*UC.8/13.—*Commonwealth of Australia: Australian Council for Aeronautics Report ACA-13: On the Concept and Properties of the Idealised Hydrodynamic Resistance. G. K. Batchelor. Council for Scientific and Industrial Research, Melbourne.* 1945.

*UC.8/14.—*Report ACA-14: Wind Tunnel Tests on Ducted Contra Rotating Fans. J. F. M. Scholes and G. N. Patterson. Council for Scientific and Industrial Research. Melbourne.* 1945.

*UC.8/15.—*Report ACA-15: Elastic Vibration of a Fan. E. R. Love and J. P. O. Silberstein. Council for Scientific and Industrial Research, Melbourne.* 1945.

UC.8/16.—*Report ACA-16: Grid Sandwich Panels in Compression. F. A. Dale and R. C. T. Smith. Council for Scientific and Industrial Research, Melbourne.* 1945.

*V.7/28.—Transactions of the Institution of Naval Architects, 1945. Institution of Naval Architects. 1945.

*Xc.B.26.—Dictionary of Aeronautical Terms H. Nelson. Pitman. 1946. 10/6.

J. Laurence Pritchard, *Secretary.*

Made and Printed in Great Britain by the Lewes Press, Lewes, Sussex.

TECHNOLOGY DEPT.

THE ROYAL AERONAUTICAL SOCIETY

4, HAMILTON PLACE, PICCADILLY, LONDON, W.1

JUNE NOTICES 1946

JOURNAL PREMIUM AWARDS

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the *Journal* and the Council hope that members (or non-members) will contribute papers on their own special subjects.

Farnborough Exhibition and Flying Display

The Royal Aircraft Establishment have arranged an Exhibition of British aircraft and engines and will have the High-Speed Tunnel, the 11ft. 6in. tunnel, the Radio Department and the Structures Department, open to visitors on Saturday, 29th June, 1946. Also, there will be a flying display which will include the Tudor, Hermes, Meteor, Vampire and other aircraft.

The display and exhibition will be open on that day to members of the Society only and one guest. Tickets, which include tea, will be limited to about 1,000, and no member of the Society or his guest will be admitted without a ticket. A car park will be provided for those arriving by road. The exhibition and display will be open from 2.30 p.m. to 7.0 p.m.

Tickets, five shillings each, can be obtained by members *only* from the Secretary, Royal Aeronautical Society, 4 Hamilton Place. The full remittance must be enclosed with each application.

Contents of June Journal

The 34th Wilbur Wright Memorial Lecture, "Recent Aerodynamic Developments," by Ernest F. Relf, C.B.E., F.R.S., Fellow; and the presentation of the Gold Medal to Professor L. Bairstow, C.B.E., F.R.S., A.R.C.S., F.I.Ae.S., Hon. Fellow.

Method of Accident Investigation and Prevention Adopted by Air Transport Auxiliary, by Philip A. Wills, C.B.E.

Correspondence on The Gas Turbine Discussion.

Northern Heights Model Flying Club

The Directors of Hawker Aircraft, Ltd., have placed Langley Aerodrome at the disposal of the above club on Sunday, the 30th of June, 1946, for a display of model flying and the latest types of full-size aircraft, including the Helicopter. The competitions will begin at 10.30 a.m. and continue until 6.30 p.m.

The club extends a warm invitation to any members of the Society who are interested. Entrance will be by programme, obtainable from the Secretary, H. R. Turner, 61 Avenell Road, Highbury, N.5.

Meeting of Council

At the 563rd Council Meeting held on the 25th April the following were present:—

Sir Frederick Handley Page (President) in the Chair; E. J. N. Archbold; Air Commodore

F. R. Banks; Sir John Buchanan; Major G. P. Bulman; Dr. H. Roxbee Cox (Vice-President); G. P. Douglas; W. S. Farren; Sir A. H. Roy Fedden (Past-President); E. T. Jones; Sir Ben Lockspeiser; P. G. Masefield; Major R. H. Mayo; W. G. A. Perring; N. E. Rowe; Sir Oliver Simmonds (Vice-President); Captain C. F. Uwins.

Among the business transacted was the following:—

The Council passed the report of the Grading Committee recommending the list of Associate Fellows and Companions for election.

The Council adopted the recommendations of the Finance Committee.

The Council agreed that the Chairman of the Finance Committee, Captain C. F. Uwins, should be the Honorary Treasurer of the Society.

A letter from the Australian Branch was read by Mr. P. G. Masefield, Member of Council, following his recent visit to Australia.

Committees of Council

The following Committees met during April:—Grading Committee; Finance Committee; Technical Policy Committee; Education and Examination Committee; Journal Committee; Engines Committee; Structures Committee; and Aerodynamics Committee.

French Scientific Office and Library

A French Scientific Office has been established in London to continue, and expand, the work done during the past two years by the French Scientific Mission.

The Office will be glad to assist members of the Society by obtaining information about meetings in France or by helping to arrange for members to visit France. Further particulars may be obtained from Miss A. M. Vidal-Hall, General Secretary, French Scientific Office, 1 Carlton Gardens, London, S.W.1.

In addition, a small scientific library is being established at the Institut Francais, which will contain a number of current scientific periodicals and some recent French scientific books. The facilities offered by the Library are consultation of the books and borrowing by post; wherever possible, arrangements will be made to obtain from France any books or periodicals not available in the Library which are specially required.

Members of the Society who wish to use the Library should write direct to The Librarian, Institut Francais, Queensberry Place, London, S.W.7, asking to be enrolled on the register. They will then be sent a catalogue of the books and periodicals available.

Graduates' and Students' Section

Visits have been arranged to the Hayes Works of the Fairey Aviation Co., Ltd., on Saturday, the 6th July and the 13th July; and on Saturday, 20th July at 2 p.m. to the Royal Aircraft Establishment, Farnborough Applications for these visits must be received not later than a week before the date of the visit by the Honorary Secretary, J. G. Roxburgh, 29 Sunningfields Road, Hendon, N.W.4.

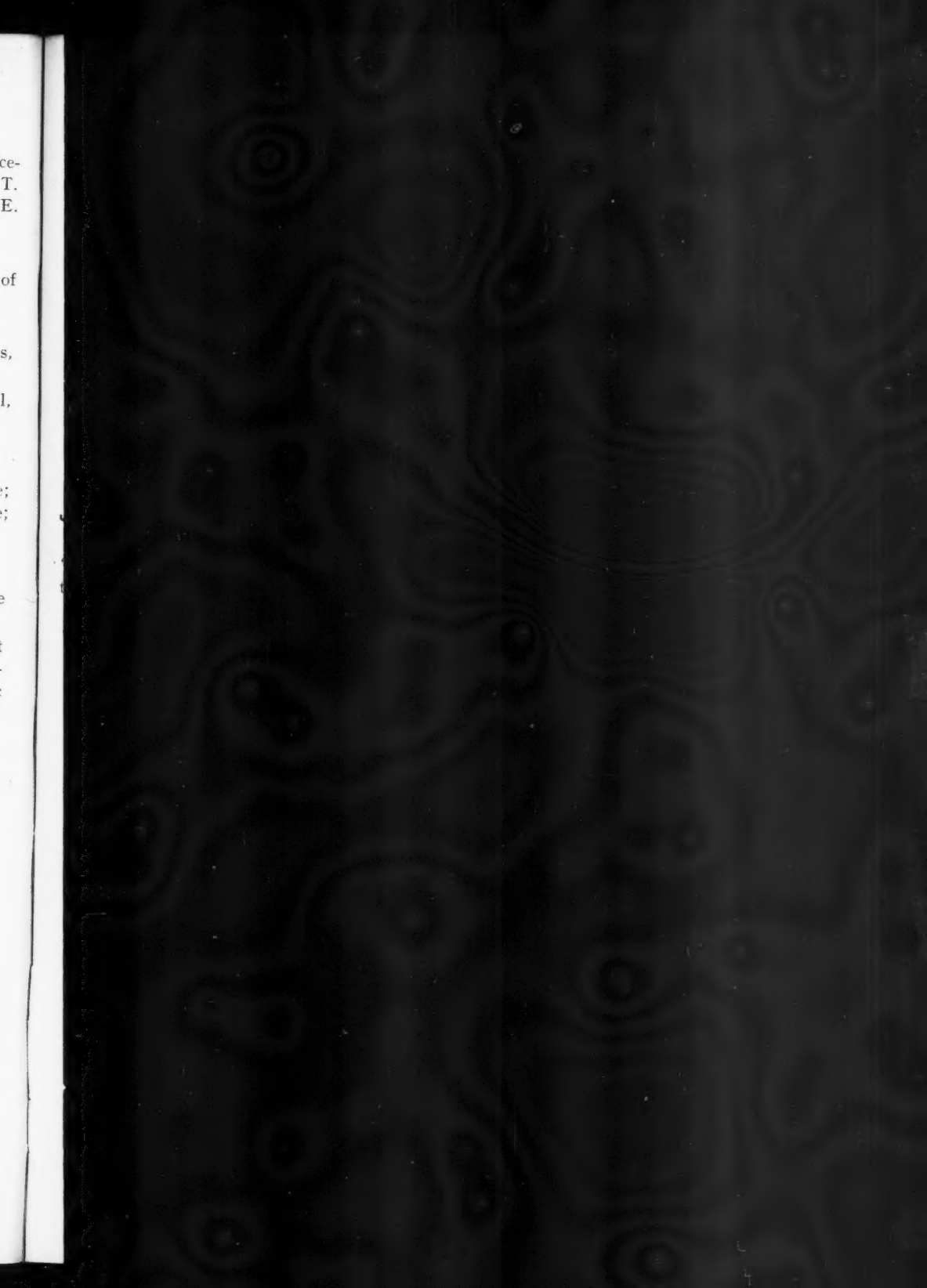
Branch Activities

BIRMINGHAM BRANCH

The following visits have been arranged:—

22nd June (morning)—Birmetals, Ltd., Woodgate, Birmingham.

13th July (afternoon)—Dowty Equipment, Ltd., Cheltenham.



Members who wish to be included in either of these visits should advise the Secretary, C. P. Homes, as soon as possible, indicating whether they can provide their own transport. Wives and fiancées of members are invited to join the visit to Cheltenham on the 13th July.

The Branch will hold its second Annual Dinner-Dance on the 7th September at the Botanical Gardens, Birmingham.

HATFIELD BRANCH

26th June—"Air Accidents and their Investigation," by Air Commodore Vernon Brown, C.B., O.B.E., M.A., F.R.Ae.S.

The meeting will be held in the Senior Staff Mess, Hatfield Aerodrome, at 6.15 p.m.

LUTON BRANCH

5th June—"Sound Measurement and Silencing," by Mr. N. Fleming, M.A. (National Physical Laboratory).

Election of Members

The following members have been elected recently:—

Fellows (all from Associate Fellows)

Leslie Aitchison, George Cornwall, Cecil Louis Cowdrey, George Robert Edwards, William Garrow-Fisher, Sydney Goldstein, William Henry Hambrook, Arnold Alexander Hall, David Frederick Lucking, Demetrius George Samaras.

Associate Fellows

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Additions to the Library

Pamphlets in italics with location reference following in brackets. Books marked * or ** may not be taken out on loan.

A.a.315.—Airplane Design—Performance. Edward P. Warner. McGraw-Hill. N.Y. 1936.

L.g.26.—The Air Almanac. Jan.-April 1946. Air Ministry. A.P. 1602.

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L.k.49.—Psychiatric Experiences of the Eighth Army Air Force. First Year of Combat. July 4 1942-July 4 1943. Major D. W. Hastings, Captains D. G. Wright and B. C. Glueck. Josiah Macey Jnr. Foundation, N.Y. 1944.

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X.a.56.—*The Air Scout Handbook.* Boy Scouts Association.

WB.17.—The Nickel Bulletin. Vol. 17. 1944. Mond Nickel Co.

Journal Advertising

The Editor regrets that in error the trade mark for Birmetals, Ltd., was inserted in the "Appreciation Section" of the advertisements in the Journal in May instead of "Birmal," the trade mark of Birmingham Aluminium Casting (1903), Ltd.

J. Laurence Pritchard, *Secretary*

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